PB88-130067

Nonmethane Organic Carbon Concentrations in Air Masses Advected into Urban Areas in the United States

Washington State Univ., Pullman

Prepared for

Environmental Protection Agency
Research Triangle Park, NC

Nov 87

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1. REPORT NO.	EPA/600/3-87/045
2.	
3. RECIPIENT'S ACCESSION NO.	PB88-130067/AS
4. TITLE AND SUBTITLE	NONMETHANE ORGANIC CARBON CONCENTRATIONS IN AIR MASSES ADVECTED INTO URBAN AREAS IN THE UNITED STATES
5. REPORT DATE	November 1987
6. PERFORMING ORGANIZATION CODE	
7. AUTHOR(S)	Hal Westberg and Lorne MacGregor
8. PERFORMING ORGANIZATION REPORT NO.	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	Laboratory for Atmospheric Research Washington State University Pullman, Washington 99164
10. PROGRAM ELEMENT NO.	A101/B/63/20-5012 (FY-87)
11. CONTRACT/GRANT NO.	CR 812208
12. SPONSORING AGENCY NAME AND ADDRESS	Atmospheric Sciences Research Laboratory-RTP, NC Office of Research and Development U.S. Environmental Protection Agency Research Triangle Park, North Carolina 27711
13. TYPE OF REPORT AND PERIOD COVERED	Final
14. SPONSORING AGENCY CODE	EPA/600/09
15. SUPPLEMENTARY NOTES	

16. ABSTRACT

The report describes recent aircraft sampling programs to measure nonmethane organic carbon (NMOC) levels aloft in the upwind vicinity of several U.S. cities during the morning period of 0600 - 0900 A.M. The cities studied included Dallas-Ft. Worth, Tulsa, Atlanta, Birmingham, Philadelphia, and New York City. Individual hydrocarbon compounds were measured using gas chromatographic procedures. The organic carbonyl compounds were collected on silica packed SEP-PAK cartridges impregnated with 2,4-dinitro phenyl hydrazine (DNPH) and analyzed by HPLC. The data collected will be used in photochemical ozone models, such as OZIPP, to determine ozone control strategies.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT RELEASE TO PUBLIC	19. SECURITY CLASS *(This Report)* UNCLASSIFIED	21. NO. OF PAGES 308
	20. SECURITY CLASS *(This page)* UNCLASSIFIED	22. PRICE

PB88-130067

EPA/600/3-87/045
November 1987

NONMETHANE ORGANIC CARBON CONCENTRATIONS IN AIR MASSES ADVECTED INTO URBAN AREAS IN THE UNITED STATES

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SPRINGFIELD, VA. 22161

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The information in this document has been funded by the United States Environmental Protection Agency under Grant No. CR-812208 to Washington State University. It has been subject to the Agency's peer and administrative review, and it has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation.

ABSTRACT

The purpose of this study was to measure non-methane organic carbon (NMOC) levels aloft in the upwind vicinity of several U.S. cities. An instrumented aircraft was employed to collect samples during the months of July and August in 1985 and 1986. NMOC, ozone and oxides of nitrogen concentrations were measured during the 0400 to 0900 period in background air masses advected into Dallas-Ft. Worth, Tulsa, Atlanta, and Birmingham in 1985 and Philadelphia and New York City in 1986. Measurements were concentrated in the layer above the morning surface inversion but below the normal afternoon mixing height. This is the air mass that would eventually mix with the surface layer within the urban area after the break-up of the morning inversion. Special emphasis was placed on NMOC speciation. Individual hydrocarbons were identified by gas chromatography (GC) and derivatized carbonyl compounds were measured by high performance liquid chromatography (HPLC). Details concerning the experimental design and quality assurance aspects of the program are provided within the report.

A tabulation of airborne data collected during the two year study period is provided. A data summary is presented for each day which includes a flight map, table of ozone and NO_x concentrations, a listing of NMOC information, and data recorded during aircraft ascents and/or descents. A brief comparison of the NMOC results obtained for the various cities investigated is also provided.

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ACKNOWLEDGEMENTS

We wish to thank the Environmental Protection Agency, Atmospheric Sciences Research Laboratory, Research Triangle Park, NC, for financial support of this work. The guidance and technical advice provided by William Lonneman was much appreciated.

Contributors to this research program included Hal Westberg, Lorne MacGregor, Fred Menzia, Dixon Arlander, Lee Bamesberger and Norm Martel.

SECTION 1

INTRODUCTION

Characterization of NMOC levels in transported air masses is currently of interest in terms of oxidant production and the formation of acidic species in the atmosphere. Organic species in the layer above a morning surface inversion and below the afternoon mixing level are of interest because oxidant precursors in this layer mix with urban plumes following breakup of the surface inversion. Most photochemical models that are designed for regulatory purposes incorporate oxidant precursors from aloft. Recent modeling studies have indicated that control requirements are quite sensitive to the concentration and composition of organics entrained from aloft (1). Therefore, it is important that NMOC concentrations in this layer be defined.

NMOC concentrations aloft have been determined in several oxidant field study programs, however, the emphasis in these previous studies was centered around urban plumes. Prior to the field work described herein, there had not been a study with the primary objective being to define NMOC levels transported into urban areas from aloft. Organic species were measured in air masses advected into Dallas, Tulsa, Atlanta, and Birmingham during the summer of 1985; Philadelphia and New York City during the summer of 1986. In this report we will summarize the types and concentrations of organic species measured aloft. Relationships between the organics and other pollutant and meteorological parameters will be described as well.

The areas investigated in 1985 were isolated urban areas whereas those investigated in 1985 were part of a complex urban area where major upwind sources may exist under certain meteorological conditions.

SECTION 2

SUMMARY AND CONCLUSIONS

The NMOC results reported for the 6 cities studied indicate that the air above urban areas for the most part represents an aged air mass that is depleted in the more reactive hydrocarbons. The average NMHC composition contains 78% paraffinic, 17% aromatic and 3% olefinic compounds. The organic carbonyl levels in 4 of the 6 urban areas contributed on the average of 10% to the total NMOC levels. The carbonyl levels at the other two sites were below detectable limits of the analytical procedure. On some flights the NMOC levels and compositions were quite consistent on each of the three sample arcs flown. At other times, however, NMOC levels and composition changed significantly. A positive correlation between NMHC and organic carbonyl levels was generally observed. The mean NMHC concentration for all cities was 22 ppbC with a coefficient of variance of 40%. Synoptic meteorological conditions are likely to have an impact on the NMOC concentration level observed in the background air. From the limited data available, it appears that the NMOC levels measured aloft agree reasonably well with those measured at remote ground level locations. More data are required to confirm this relationship.

SECTION 3

EXPERIMENTAL PROCEDURES

The aircraft flew arcs upwind of the urban areas during the early morning hours. On most days, there were three arcs flown at two different altitudes above the morning surface inversion but below the normal afternoon mixing height. Figure 1 provides a schematic illustration of the flight pattern. Sample collection involved transferring air from a ram-air manifold inside the aircraft to the collection medium. For hydrocarbons, this entailed filling a metal canister to a positive pressure with a metal bellows pump. Carbonyl compounds were trapped by passing air through adsorbent cartridges impregnated with dinitrophenyl hydrazine. The hydrazones that formed were analyzed by HPLC (2). An attempt was made to measure PAN levels aloft by collecting air samples in Tedlar bags and measuring the PAN content by EC-GC immediately after the aircraft landed. Analytical difficulties along with the absence of a reliable field calibration standard compromised the quality of the PAN data and consequently it is not included in this report.

Ozone, NO_x, temperature and relative humidity were measured continually in the aircraft. These parameters were employed to define the morning mixing level as well as to provide additional information for modeling the urban photochemistry.

A complete description of the air quality instrumentation used, calibration methods and data processing and validation procedures is included in Appendix G.

Winds reported at 3000 feet were obtained from the local flight service station. This information was used to plan the location of upwind flight paths each morning.

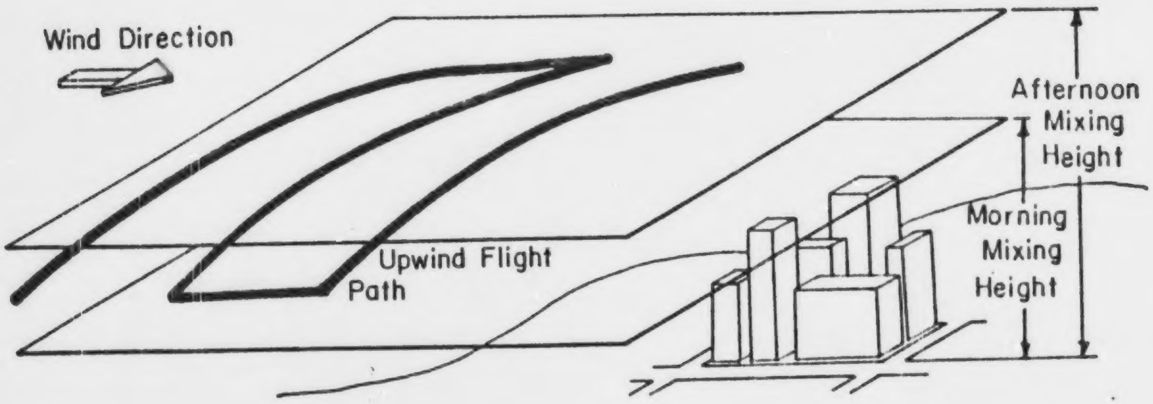
Wind Direction
Upwind Flight
Path
Afternoon
Mixing
Height
Morning
Mixing
Height

Figure 1. Schematic diagram of aircraft flight pattern.

SECTION 4

RESULTS AND DISCUSSION

Table 1 provides a summary of the average non-methane hydrocarbon (NMHC) and aldehyde concentrations measured aloft over the six cities. Mean hydrocarbon concentrations varied between 14 and 39 ppbC with the highest average concentrations recorded upwind of Tulsa. The low mean value determined in Birmingham may not be truly representative of that particular urban area. The morning flights were plagued with bad flying weather while in Birmingham and consequently fewer samples were collected. The mean NMHC concentration for all cities combined was 22 ppbC with a coefficient of variance of approximately 40%. Paraffinic species were by far the major class of hydrocarbons measured aloft. These compounds comprised approximately 78% of the identified hydrocarbons while the mean aromatic contribution was about 17% and the olefins averaged 3%.

Table 1. Mean NMHC Concentrations Measured Aloft

City	Sampling Dates	Identified NMHC (ppbC)	Formaldehyde (ppb)	Acetaldehyde (ppb)
Dallas	July 5-14, 1985	23	1.7	0.2
Tulsa	July 16-24, 1985	34	3.5	0.9
Atlanta	Aug. 13-23, 1985	25	<0.7	<0.3
Birmingham	Aug. 26-29, 1985	14	<0.7	<0.3
Philadelphia	July 8-Aug. 14, 1986	16	1.8	0.7
New York City	July 8-Aug. 14, 1986	19	1.9	0.7

Formaldehyde and acetaldehyde levels in Atlanta and Birmingham were generally below the detection limit of the analytical procedure. In Dallas, Tulsa, Philadelphia and New York City the two carbonyls accounted for about 10% of NMOC that was identified. A positive correlation between NMHC and aldehyde concentrations was generally observed. For example, NMHC levels upwind of Dallas on the morning of July 6, 1985 averaged 30 ppbC with a corresponding mean aldehyde concentration of about 2 ppb. On July 14, Dallas NMHC levels were down to about 4 ppbC and the aldehyde concentrations ranged from below the detection limit (~0.1 ppb) up to 0.7 ppb (see Table 2).

The data base makes it possible to examine the variability in NMHC concentrations aloft during the morning hours since sampling arcs were flown at different distances and altitudes upwind of the urban area. Generally, one or more samples were collected along each of three upwind arcs. Figure 2 graphically illustrates the daily variations in NMHC levels observed in each of the six areas. The horizontal lines in Figure 2 represent measured NMHC levels in individual samples. The vertical lines connect maximum and minimum levels each day. On most days, the high NMHC measurement exceeds the low value by at least a factor of two and on several occasions by as much as a factor of ten. As can be seen in Figure 2, on days when the NMHC concentration range was large, one sample exhibited a much higher hydrocarbon level than others. The reason for this anomalous behavior is not immediately obvious. The high readings showed no consistent correlation with altitude or distance from the city.

NMHC compositions were generally consistent from city to city; however, influences from selected source types were periodically observed. For example in Tulsa occasional elevated levels of the C_2 to C_4 paraffinic hydrocarbons were observed, possibly from the refineries located upwind of the city. In Atlanta relatively large concentrations of toluene were occasionally observed. The upwind source for this compound was not identified.

Table 2. Summary of Airborne Data Collected Upwind of Dallas on July 6 and 14, 1985

Date	Arc (mi)	Alt (ft)	NMHC (ppbC)	Formaldehyde (ppb)	Acetaldehyde (ppb)	O_3 (ppb)	NO_x (ppb)
July 6	15	2000	22.4	1.5	0.5	~50	~15
	20	3000	36.7	1.6	0.7		
	25	2000	15.3	1.4	<0.2		
July 14	25	2000	3.8	0.1	<0.2	~20	~5
	20	3000	-	0.3	<0.2		
	15	2000	4.7	0.7	0.7		

Also of interest is the correlation of NMOC aloft with other pollutants. Generally speaking, there appeared to be a direct relationship between NMOC concentrations with ozone and NO_x levels. For example, Table 2 summarizes NMOC, O_3 and NO_x data collected upwind of Dallas on the mornings of July 6 and 14, 1985. It is evident that elevated NMOC levels on July 6 are associated with ozone and NO_x concentrations which are considerably higher than those recorded on July 14.

Philadelphia and New York City were chosen for a preliminary examination of possible correlations between weather patterns and oxidant precursor levels in the air advected from aloft. Because they are geographically close, it is expected that they would receive air masses from the same source areas under westerly and northwesterly flow conditions.

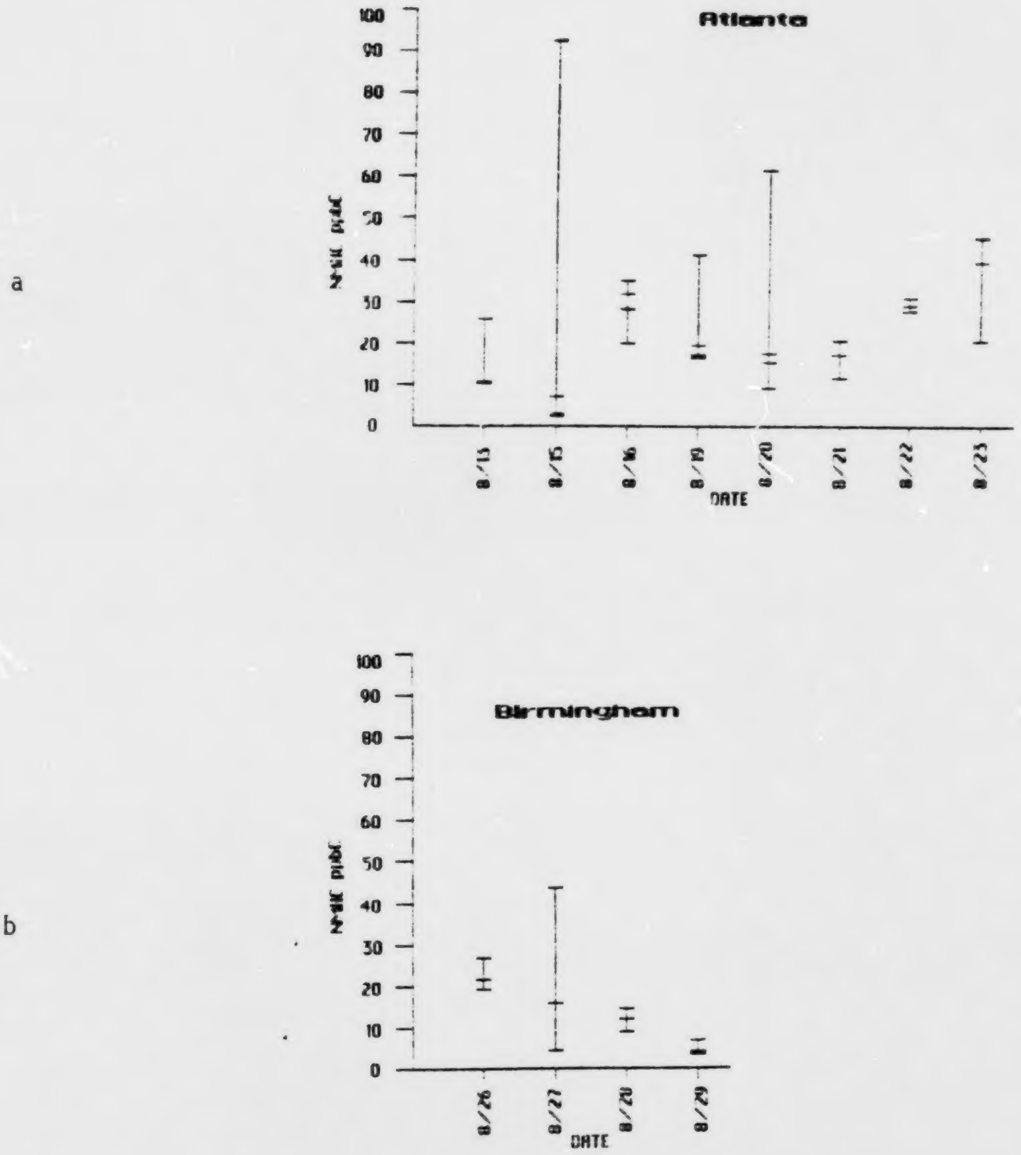

Figure 2. Variability in daily NMHC concentrations observed in a)Atlanta, b) Birmingham, c) Dallas, d)Tulsa, e) New York City, and f) Philadelphia

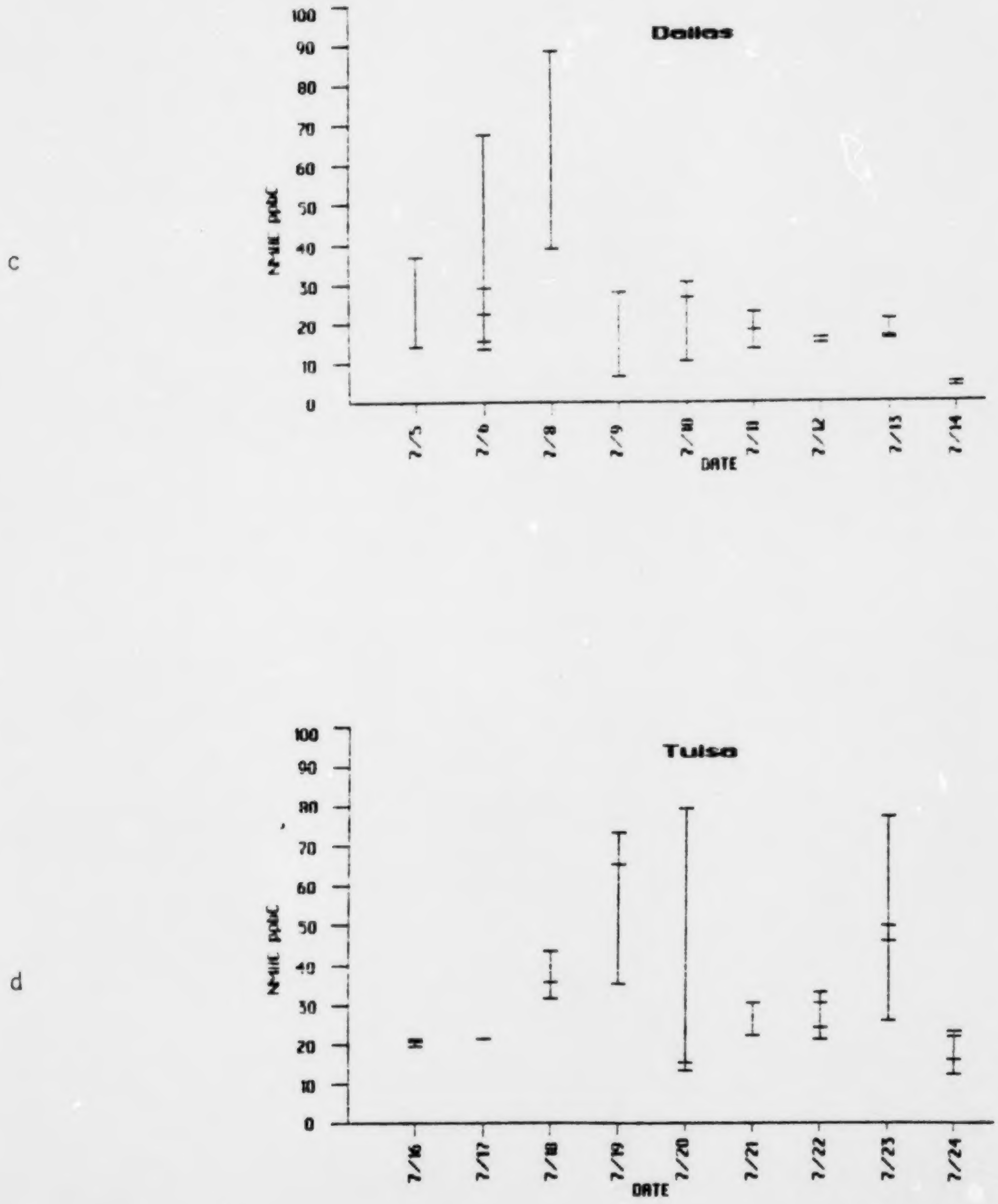

Figure 2. Continued.

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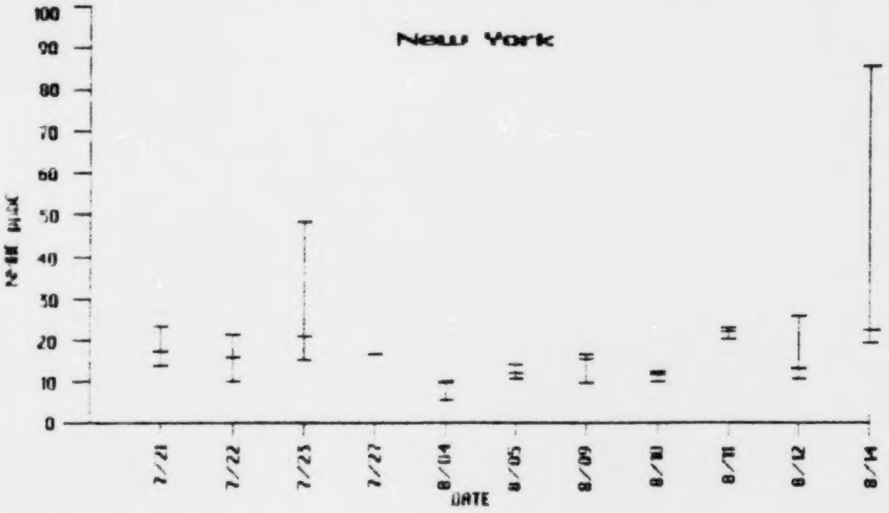

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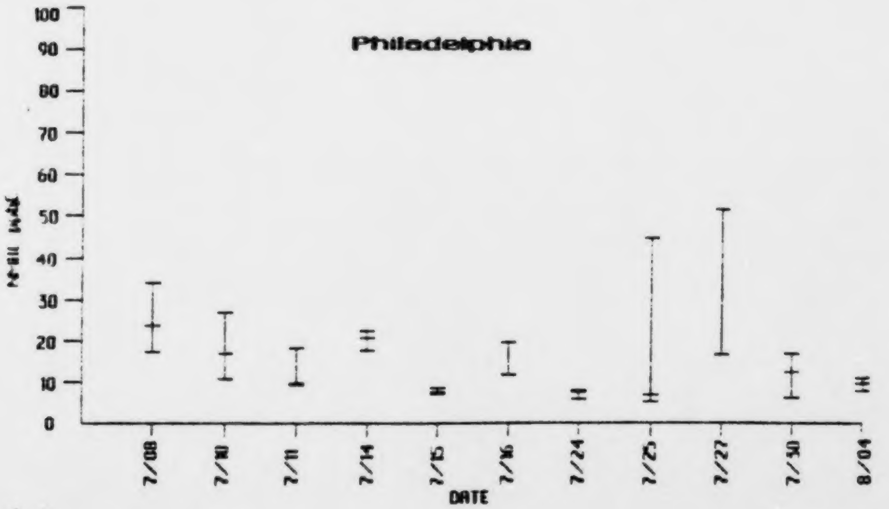

Figure 2. Continued.

Two sets of days with similar morning wind speed and direction are compared in Table 3. In the first group, which includes two days with westerly winds exceeding 20 kts, oxidant precursor levels are nearly identical. The maximum ozone levels recorded at surface stations in each of the urban areas on July 14 and August 8 were very comparable, as well. A similar pattern exists for the two days listed with westerly winds less than 10 kts. Precursor levels are very comparable as are the surface ozone concentrations which in this case are elevated when compared to the high wind conditions of the first group. The fact that higher surface ozone levels are recorded under more stagnant meteorological conditions agrees with expectations.

Figure 3 shows the average NMOC concentrations measured aloft during this study and compares them to the concentrations measured at a rural, surface site near State College, Pennsylvania (3) and on the ground in Philadelphia (4). As is readily apparent, NMOC concentrations at the rural site are comparable to those found aloft and much less than those measured in Philadelphia. The NMHC levels recorded in the urban area are on the order of twenty times those observed in the background air while the aldehyde levels are three to four times that found aloft or at the rural site. Since the rural surface NMOC levels are comparable to those collected aloft, it appears that surface data could be utilized as boundary condition values for modeling urban oxidant production when aircraft data is not available.

Table 3. Oxidant Precursors and Wind Data

Date	City	Wind Speed (kts)	Wind Direction (deg)	Ident. NMHC (ppbC)	Aldehyde (ppb)	NO_x (ppb)	Peak Surface O_3 (ppb)*
07/14	P	25	290	20.1	2.8	3	62
08/11	NY	22	270	21.8	2.7	4	64
07/16	P	8	290	15.5	5.0	3	114
07/22	NY	7	290	15.6	3.3	3	107

P = Philadelphia
NY = New York

* The O_3 data was taken from SAROAD sites 310720003F01 for 7/14, from 330280002F01 for 8/11, from 311760002F01 for 7/16, and from 313260001F01 for 7/22.

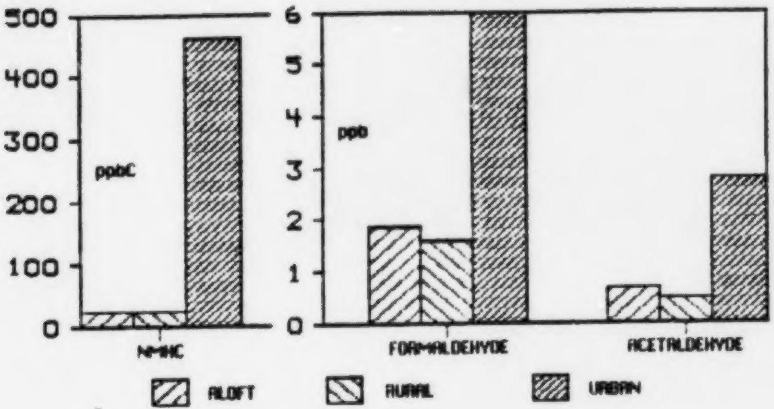

Figure 3. Comparison of average NMOC concentrations measured at 1) a rural surface site in Pennsylvania, 2) urban Philadelphia, and 3) aloft in the vicinity of Atlanta, Birmingham, Dallas, Tulsa, New York City and Philadelphia.

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3. H. H. Westberg, J. C. Farmer, B. K. Lamb and D. W. Arlander, Relationship Between Ambient Concentrations of Hydrocarbons, Aldehydes and Organic Acids, EOS 67, 891 (1986).

4. NMOC and NO_x Measurements at Five Surface Sites in Philadelphia, Final Report for EPA Grant No. CR812208, (in preparation).

APPENDIX A

Aircraft Flight Maps and Pollutant Measurement Data Obtained from Dallas-Ft. Worth, Texas

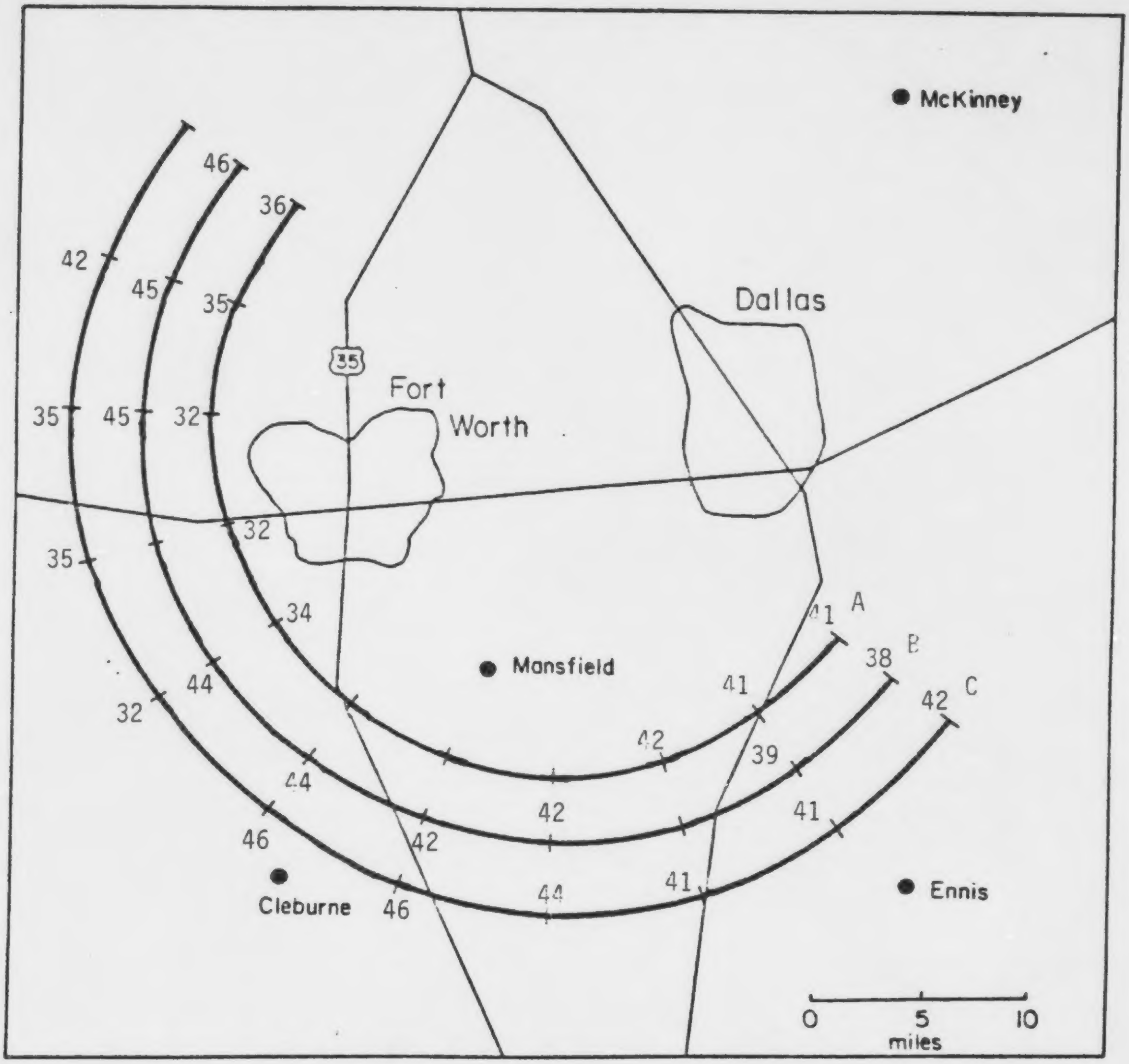
DALLAS-FT. WORTH AIR QUALITY DATA

This section provides a tabulation of airborne data collected in the Dallas-Ft. Worth area during the period July 5-14, 1985. For each sampling day, there is a flight map with ozone concentrations marked along the route, a tabulation of air quality data, a listing of individual hydrocarbon concentrations and a graphical summary of ozone, NO_x and temperature changes with altitude.

NOTES on Hydrocarbon Tables

*	Means data not available
-	Means concentration less than 0.1 ppbC
( )	Ethylene values in parentheses were calculated by multiplying the propane concentration by 0.18. This was necessary in cases of obvious ethylene contamination due to the presence of a chemiluminescent ozone analyzer. The ethylene-propane ratio was derived from airborne samples that were free of contamination problems.

TNMHC is the sum of all gas chromatographic peaks


McKinney
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Fort Worth
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Mansfield
Cleburne
Ennis
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41
0
5
10
miles

Figure A-1. July 5 flight path with ozone concentrations (ppb) marked along the route.

Time (CDT) and Altitude (AGL)

A: 0713 - 0751 at 2000'

B: 0757 - 0839 at 3000'

C: 0843 - 0914 at 2000'

Wind: 270° at 9 knots

July 5, 1985

Morning Mixing Level: 1150 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/130		07:13:05	41	6	18	22.6			
A/148		07:16:45	41	7	19	23.0			
A/166		07:20:35	42	7	16	22.2			
A/184		07:24							
A/202		07:28							
A/220	2000'	07:32					36.7	0.7	<0.2
A/238		07:35:52	34	7	12	23.5			
A/256		07:39:32	32	6	13	23.0			
A/274		07:43:23	32	7	13	23.5			
A/292		07:47:13	35	7	11	24.5			
A/310		07:51:03	36	6	11	24.7			
B/310		07:57:03	46	5	11	25.3			
B/292		08:01:13	45	4	11	24.3			
B/274		08:05:24	45	5	13	23.8			
B/256		08:09							
B/238		08:13:54	44	6	10	21.6			
B/220	3000'	08:18:04	44	5	10	24.1	7.6	0.4	0.3
B/202		08:22:14	42	4	8	24.2			
B/184		08:26:24	42	5	9	23.0			
B/166		08:30:44	41	6	9	21.9			
B/148		08:34:54	39	3	10	22.2			
B/130		08:39:04	38	4	10	22.4			
C/130		08:43:04	47	4	11	22.2			
C/148		08:46:06	41	4	10	22.2			
C/166		08:49							
C/184		08:52:16	44	4	9	22.4			
C/202		08:55:26	46	3	11	22.5			
C/220	2000'	08:58:27	46	4	10	22.5		0.7	<0.2
C/238		09:01:37	37	6	8	23.1			
C/256		09:04:46	35	4	8	23.6			
C/274		09:07:47	35	4	7	24.0			
C/292		09:10:57	42	5	8	25.1			
C/310		09:13							

* See flight map for Arc; Radial off DFW VOR.

Table A-1. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 5, 1985

Hydrocarbon	A/C Arc A 0723 - 0745 (CDT)	A/C Arc B 0811 - 0820 (CDT)
Ethane	11.4	2.7
Ethylene	(0.6)	(0.2)
Acetylene	0.5	*
Propane	3.2	1.3
Propene	-	0.7
i-Butane	0.1	*
n-Butane	8.9	0.7
i-Pentane	1.7	*
n-Pentane	1.3	*
Cyclopentane	-	-
Isoprene	0.2	-
2,3-Dimethylbutane	0.1	-
2-Methylpentane	0.6	-
3-Methylpentane	0.4	-
n-Hexane	0.7	-
Methylcyclopentane	0.4	-
Benzene	2.5	0.9
Cyclohexane	0.9	-
2-Methylhexane	0.1	-
3-Methylhexane	-	-
2,2,4-Trimethylpentane	-	-
Toluene	1.4	1.1
n-Octane	1.4	-
Ethylbenzene	-	*
p & *m*-Xylene	0.3	*
o-Xylene	-	*
Total Identified HC	36.7	7.6
TOTAL NMHC	69.1	13.9
% Paraffins	86	80
% Olefins	2	6
% Aromatics	11	14

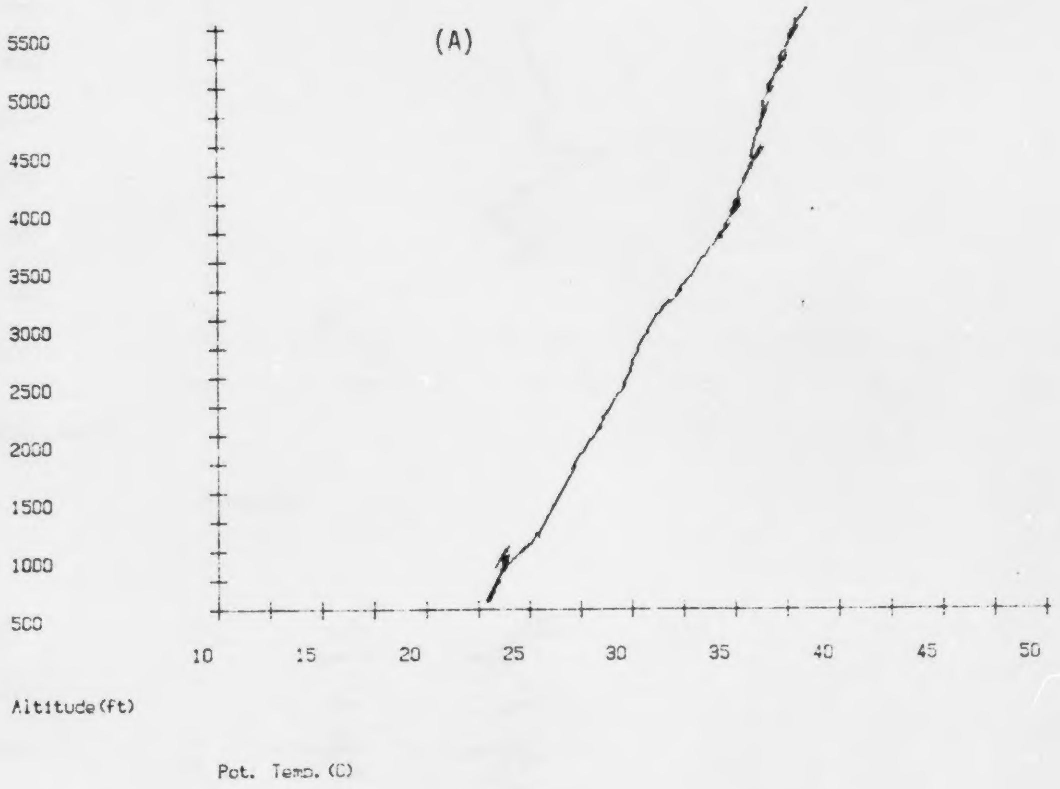
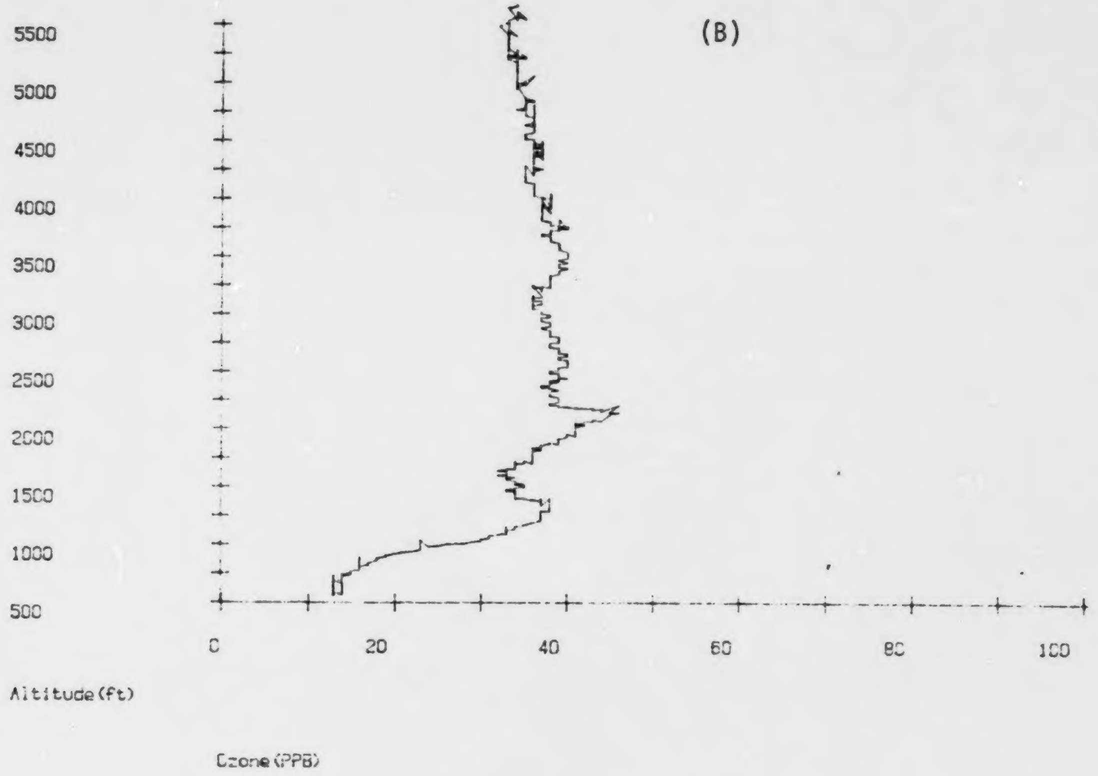
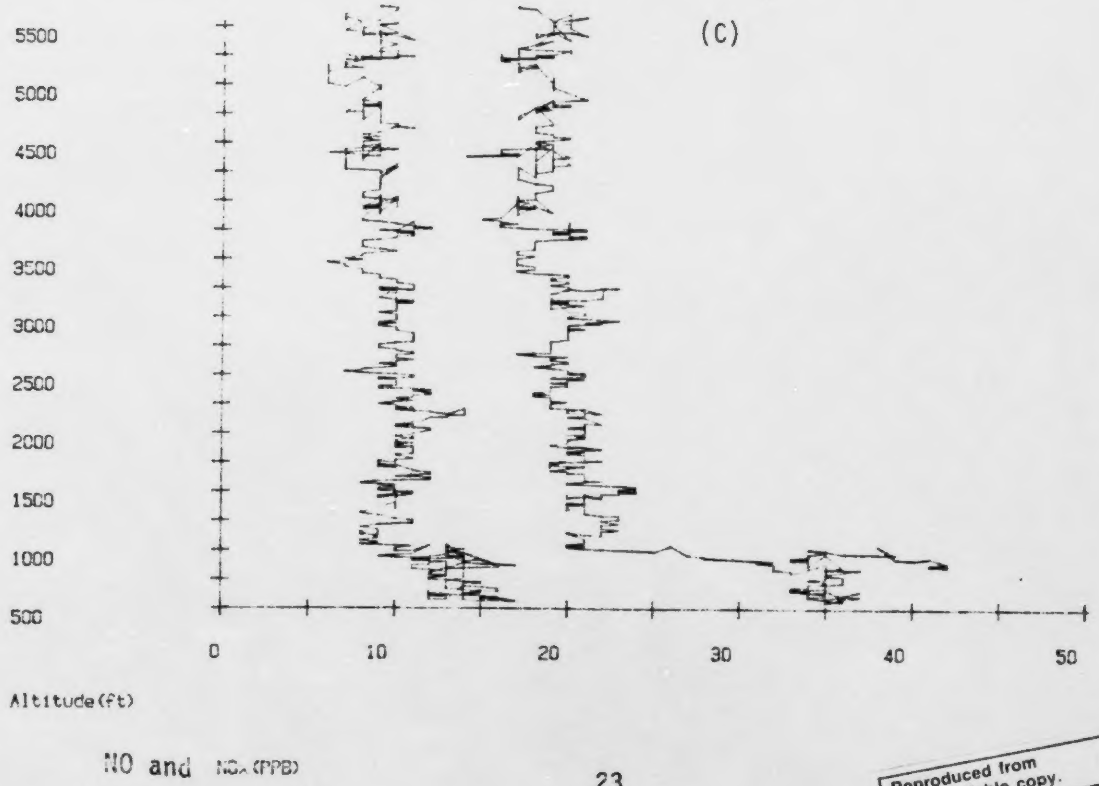


Figure A-2. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on July 5, 1985.

(Figure A-2. cont'd.)





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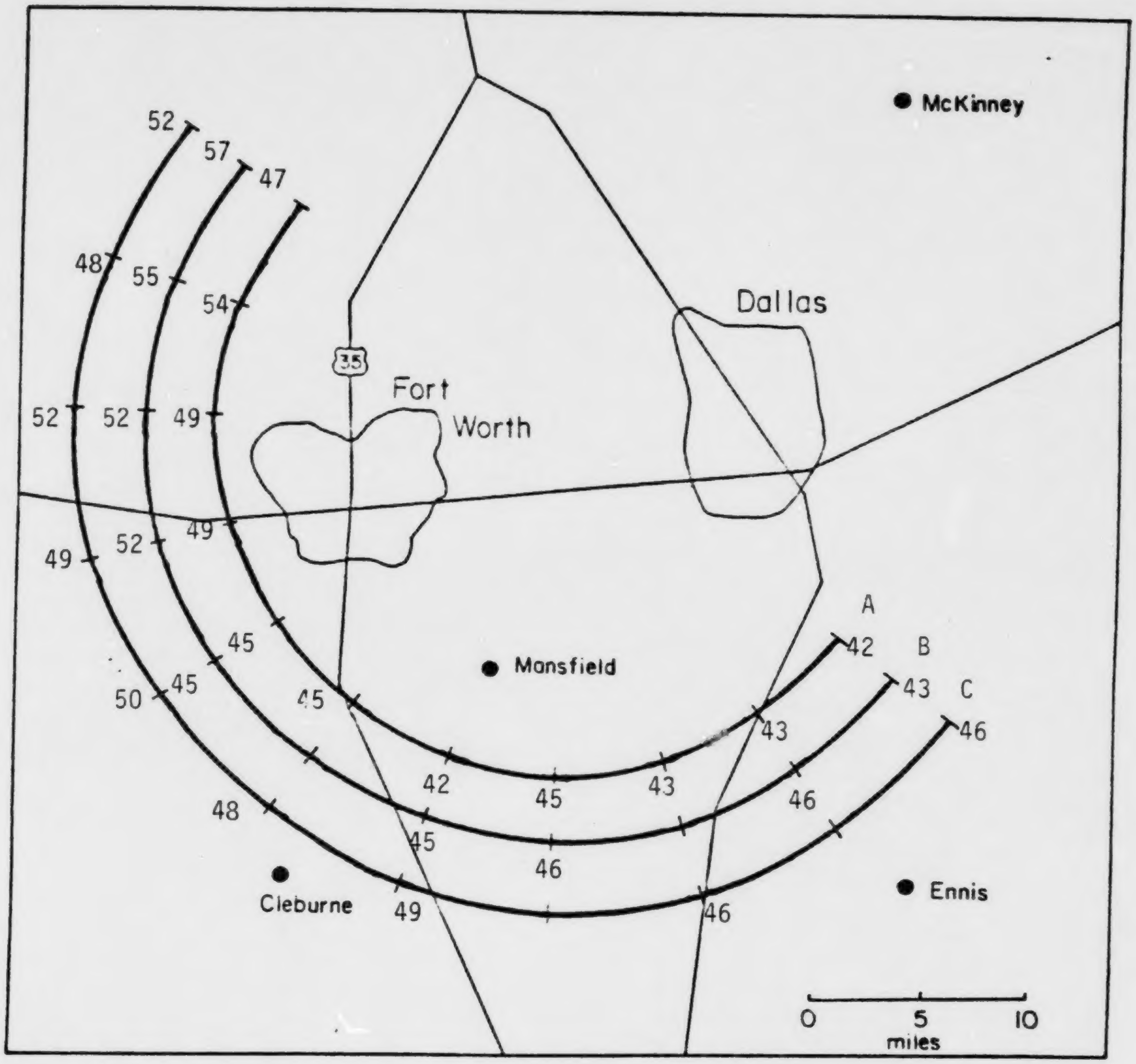
McKinney
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Cleburne
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miles

Figure A-3. July 6 flight path with ozone concentrations (ppb) marked along the route.

Time (CDT) and Altitude (AGL)

A: 0627 - 0705 at 2000'

B: 0710 - 0752 at 3000'

C: 0756 - 0839 at 2000'

Wind: light and variable

July 6, 1985

Morning Mixing Level: 560 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/130		06:27:05	42	10	21	24.8			
A/148		06:30:56	43	10	18	24.7			
A/166		06:34:47	43	9	17	24.5			
A/184		06:38:37	45	8	17	25.0			
A/202		06:42:37	42	7	17	24.6			
A/220	2000'	06:46:27	45	7	15	24.9	22.4	1.5	0.5
A/238		06:50:37	45	9	16	24.9			
A/256		06:54:07	49	8	16	25.1			
A/274		06:58:08	49	7	12	25.4			
A/292		07:01:58	54	7	14	25.8			
A/310		07:05:48	47	7	16	25.5			
B/310		07:10:30	57	6	14	23.8			
B/292		07:14:41	55	7	14	23.8			
B/274		07:18:51	52	6	12	23.9			
B/256		07:23:01	52	6	15	24.2			
B/238		07:27:01	45	6	12	24.1	28.9		
B/220	3000'	07:31					67.8	1.6	0.7
B/202		07:35:28	45	6	13	23.7	13.5		
B/184		07:39:29	46	5	11	23.7			
B/166		07:43:39		5	10	23.6			
B/148		07:47:50	46	4	9	23.4			
B/130		07:52:00	43	5	7	23.2			
C/130		07:55:55	46	4	11	25.1			
C/148		08:00:15		5	9	25.3			
C/166		08:04:25	46	6	11	25.2			
C/184		08:08:45		4	8	25.6			
C/202		08:13:07	49	4	10	25.8			
C/220	2000'	08:17:27	48	5	8	26.0	15.3	1.4	<0.2
C/238		08:21:37	50	5	8	26.1			
C/256		08:25:57	49	5	7	26.3			
C/274		08:30:19	52	4	10	26.6			
C/292		08:34:30	48	5	10	26.3			
C/310		08:38:50	52	7	12	25.8			

* See flight map for Arc; Radial off DFW VOR.

Table A-2. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 6, 1985

Hydrocarbon	A/C Arc A 0645 - 0653 (CDT)	A/C Arc B 0712 - 0719 (CDT)	A/C Arc B 0727 - 0734 (CDT)
Ethane	4.1	4.7	4.5
Ethylene	(0.2)	(0.4)	(3.0)
Acetylene	0.1	0.6	0.6
Propane	0.9	2.5	16.9
Propene	*	*	*
i-Butane	*	1.0	1.5
n-Butane	1.9	2.5	2.5
i-Pentane	1.3	1.7	1.0
n-Pentane	0.6	1.2	0.8
Cyclopentane	-	-	-
Isoprene	-	-	-
2,3-Dimethylbutane	0.1	0.1	-
2-Methylpentane	0.4	0.4	-
3-Methylpentane	0.2	-	-
n-Hexane	0.3	0.3	-
Methylcyclopentane	0.1	0.1	-
Benzene	1.1	1.1	2.1
Cyclohexane	-	-	-
2-Methylhexane	0.1	0.1	-
3-Methylhexane	1.1	1.0	2.0
2,2,4-Trimethylpentane	0.2	-	-
Toluene	1.6	0.9	4.0
n-Octane	2.4	9.7	24.8
Ethylbenzene	1.1	0.1	-
p & *m*-Xylene	1.9	0.3	0.4
o-Xylene	2.7	0.2	3.7
Total Identified HC	22.4	28.9	67.8
TOTAL NMHC	37.3	37.7	86.9
% Paraffins	61	89	80
% Olefins	1	1	4
% Aromatics	38	9	15

Table A-2. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 6 cont'd.

Hydrocarbon	A/C Arc B 0741 - 0748 (CDT)	A/C Arc C 0812 - 0819 (CDT)
Ethane	3.4	3.8
Ethylene	(0.3)	(0.3)
Acetylene	0.2	0.2
Propane	1.5	1.8
Propene	*	0.3
i-Butane	1.0	1.4
n-Butane	1.3	1.3
i-Pentane	0.8	1.3
n-Pentane	0.6	0.6
Cyclopentane	-	-
Isoprene	-	-
2,3-Dimethylbutane	-	0.1
2-Methylpentane	0.2	0.2
3-Methylpentane	-	-
n-Hexane	-	-
Methylcyclopentane	-	-
Benzene	1.4	0.9
Cyclohexane	-	*
2-Methylhexane	-	0.2
3-Methylhexane	1.3	1.5
2,2,4-Trimethylpentane	-	0.2
Toluene	0.8	0.8
n-Octane	0.7	*
Ethylbenzene	*	-
p & *m*-Xylene	*	0.2
o-Xylene	*	0.2
Total Identified HC	13.5	15.3
TOTAL NMHC	14.5	25.4
% Paraffins	*	81
% Olefins	*	4
% Aromatics	*	14

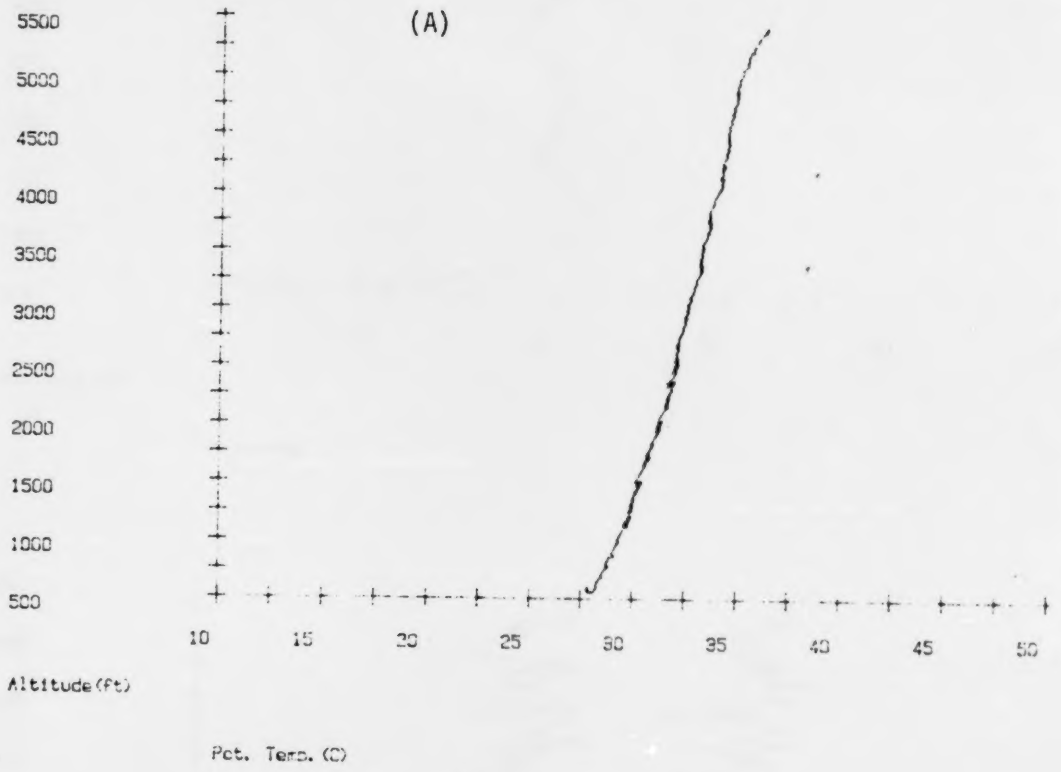
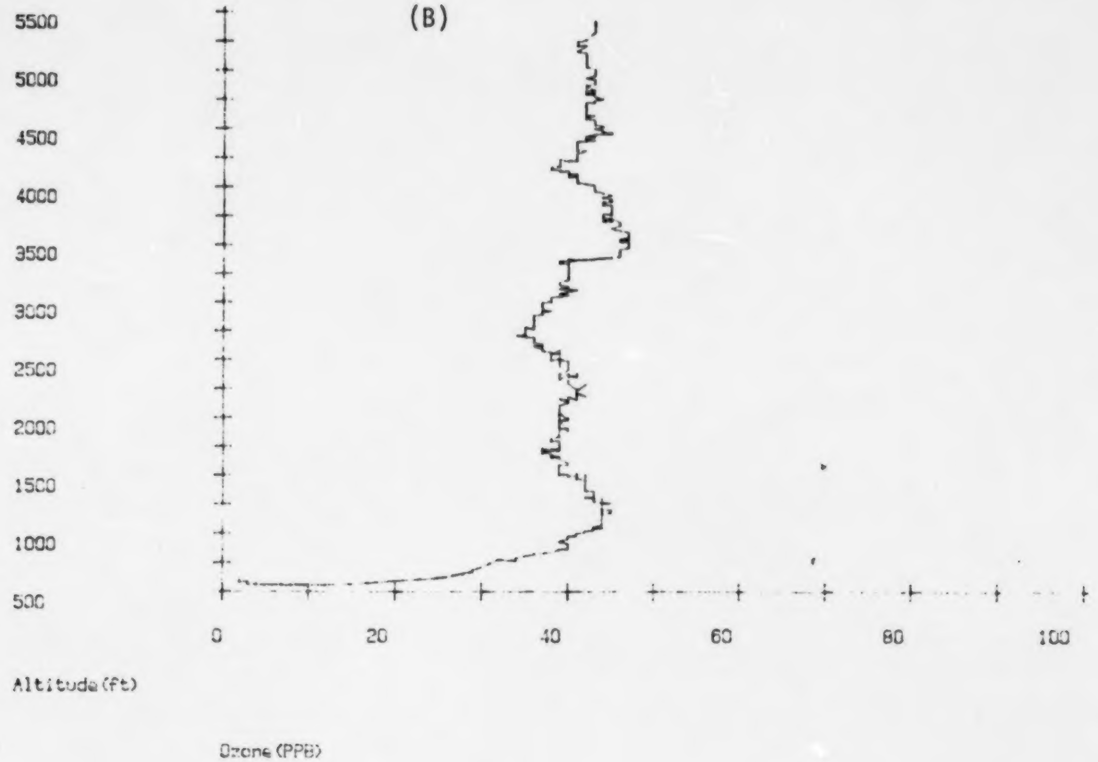
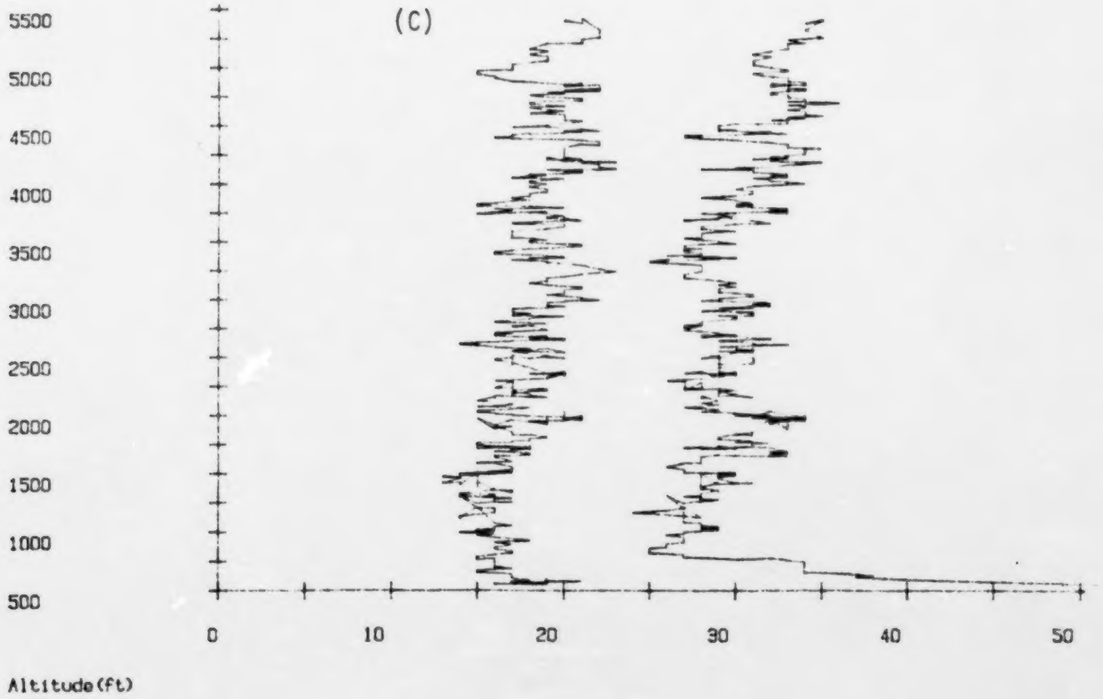
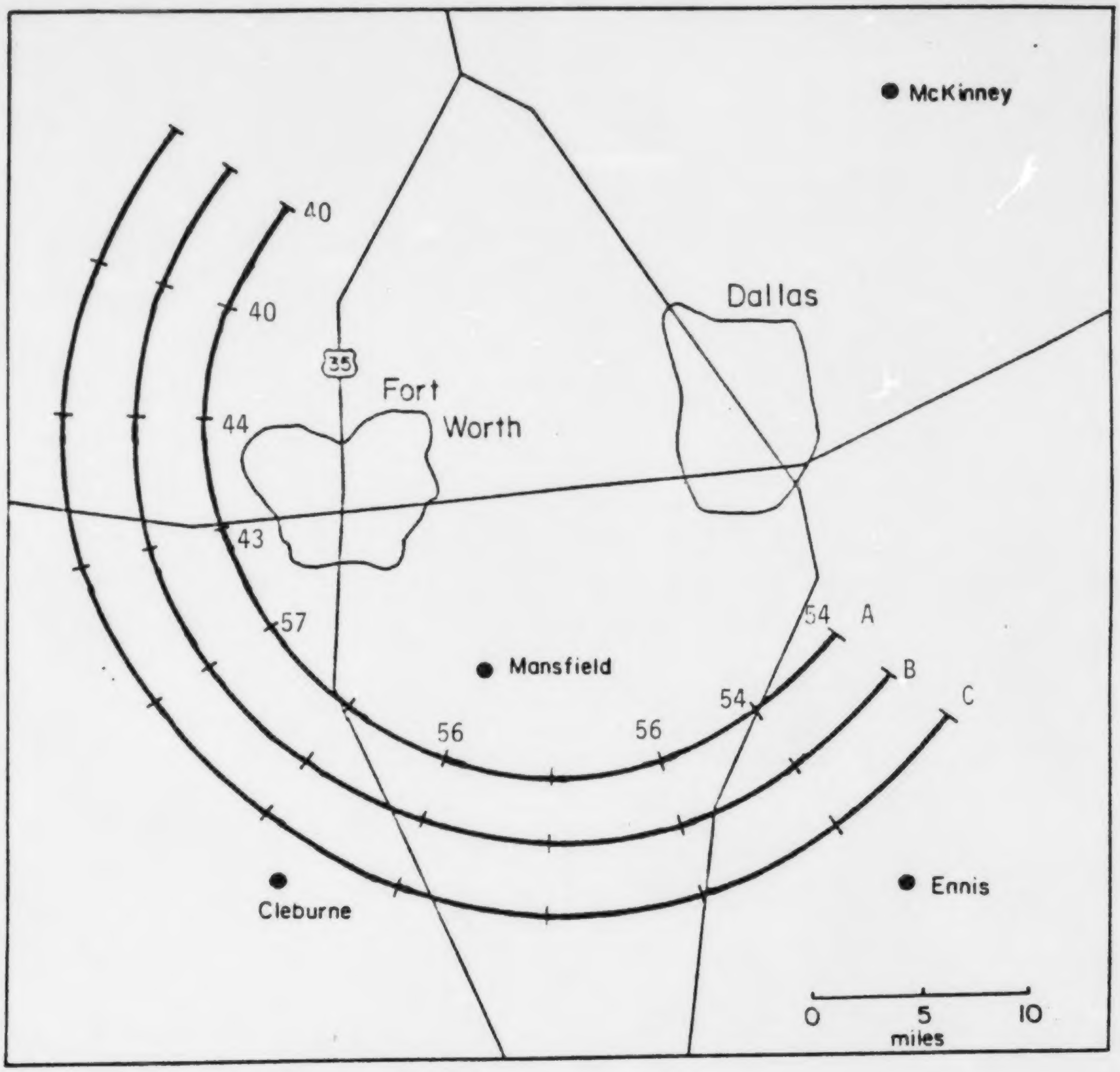


Figure A-4. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on July 6, 1985.

(Figure A-4. cont'd.)







McKinney
Dallas
Fort Worth
35
Mansfield
Cleburne
Ennis
40
40
44
43
57
56
56
54
54
A
B
C
0
5
10
miles

Figure A-5. July 7 flight path with ozone concentrations (ppb) marked along the route.

Time (CDT) and Altitude (AGL)

A: 0610 - 0646 at 2000'

B: Aborted due to weather

C: Aborted due to weather

Wind: light and variable

July 7, 1985

Morning Mixing Level: 1120 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/130		06:10:10	54	14	17	24.1			
A/148		06:13:40	54	11	19	24.0			
A/166		06:17:20	56	11	20	24.0			
A/184		06:20							
A/202		06:24:25	56	10	16	23.9			
A/220	2000'	06:27:55		10	18	23.8		5.8	<0.2
A/238		06:31:35	57	8	14	23.6			
A/256		06:35:05	43	11	17	23.2			
A/274		06:38:36	44	9	16	23.3			
A/292		06:42:17	40	9	16	23.3			
A/310		06:45:47	40	9	14	23.5			

* See flight map for Arc; Radial off DFW VOR.

Table A-3. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 7, 1985

Hydrocarbon	A/C Arc A 0626 - 0636 (CDT)
Ethane	9.8
Ethylene	(1.6)
Acetylene	0.5
Propane	8.8
Propene	0.8
i-Butane	2.3
n-Butane	4.8
i-Pentane	2.7
n-Pentane	1.4
Cyclopentane	*
Isoprene	*
2,3-Dimethylbutane	*
2-Methylpentane	*
3-Methylpentane	*
n-Hexane	*
Methylcyclopentane	*
Benzene	*
Cyclohexane	*
2-Methylhexane	*
3-Methylhexane	*
2,2,4-Trimethylpentane	*
Toluene	*
n-Octane	*
Ethylbenzene	*
p & *m*-Xylene	*
o-Xylene	*
Total Identified HC	*
TOTAL NMHC	*
% Paraffins	*
% Olefins	*
% Aromatics	*

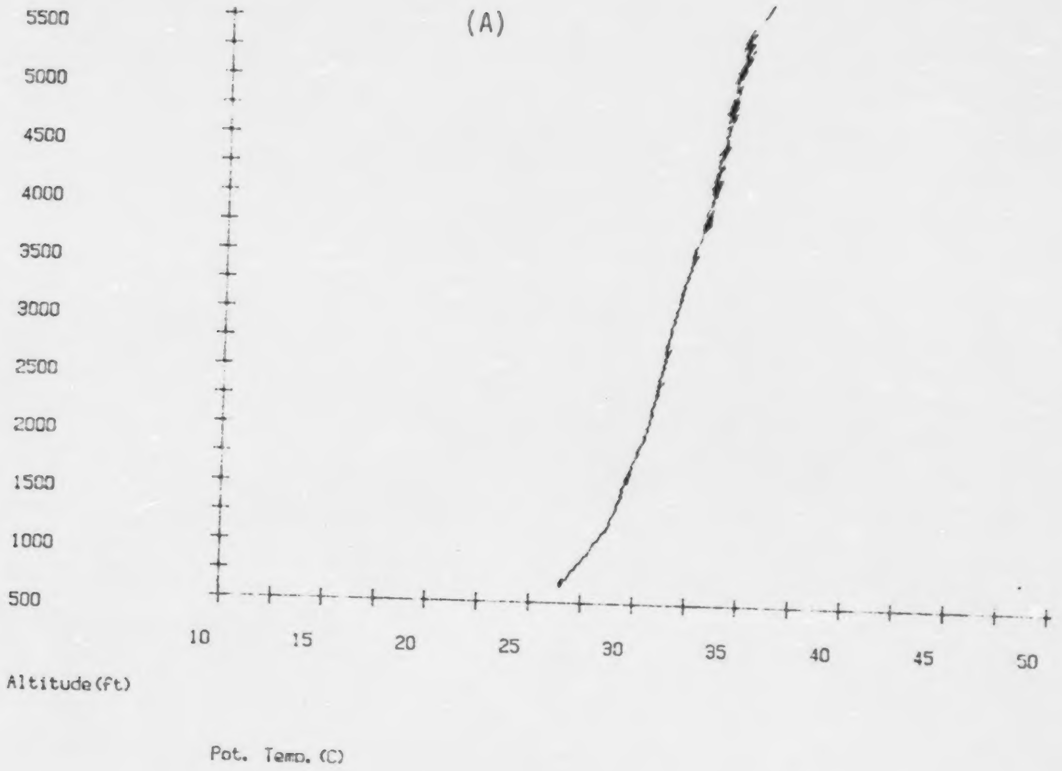
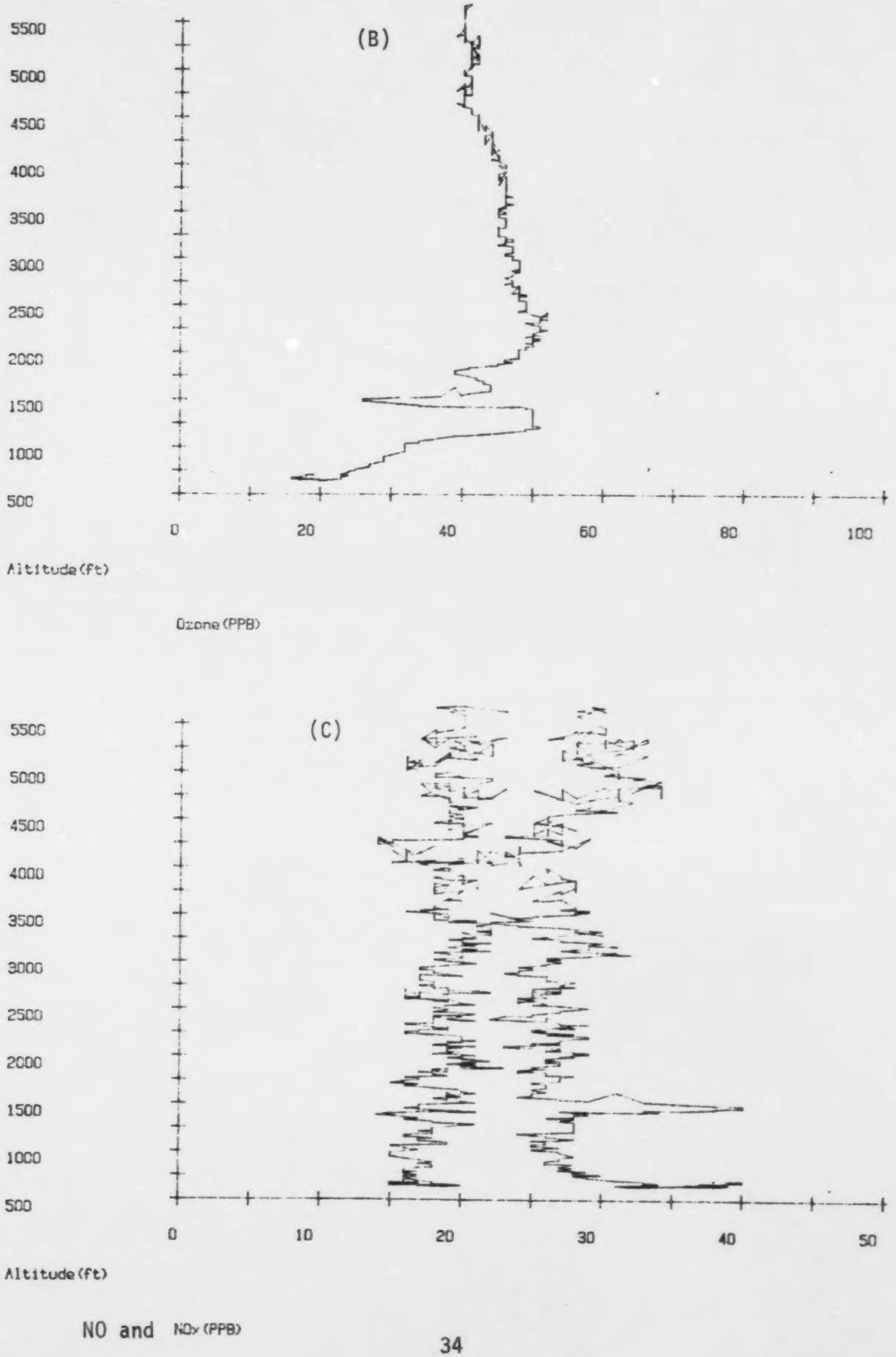


Figure A-6. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on July 7, 1985.

(Figure A-6, cont'd.)



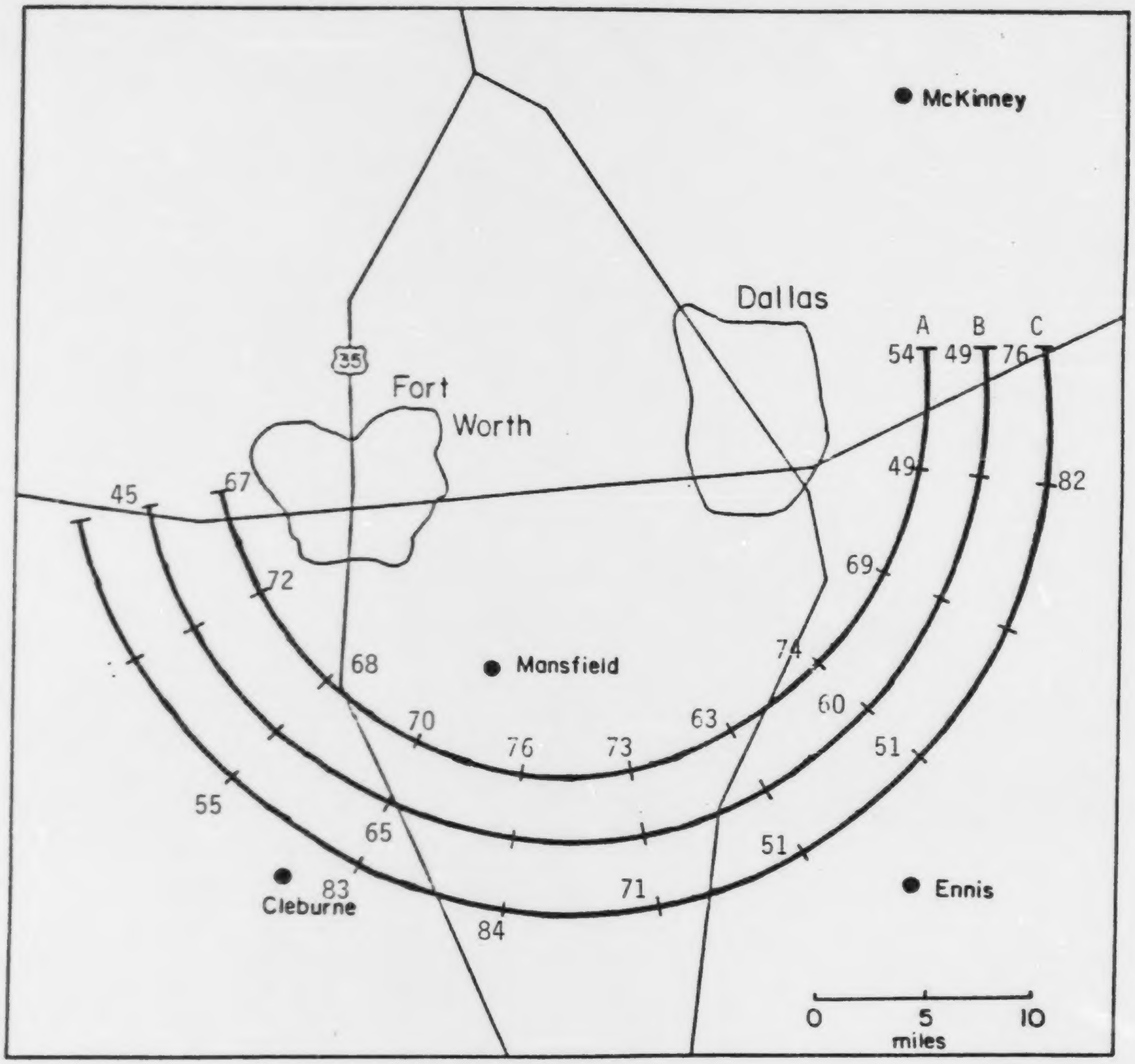

McKinney
Dallas
A
B
C
54
49
76
35
Fort
Worth
45
67
49
82
69
72
74
68
Mansfield
60
63
70
76
73
51
55
65
51
83
Cleburne
71
84
Ennis
0
5
10
miles

Figure A-7. July 8 flight path with ozone concentrations (ppb) marked along the route.

Time (CDT) and Altitude (AGL)

A: 0642 - 0722 at 2000'

B: 0729 - 0808 at 3000'

C: 0814 - 0902 at 2000'

Wind: 170° at 17 knots

July 8, 1985

Morning Mixing Level: 825 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/080	2000'	06:42:43	54	12	21	23.9	88.6	4.3	<0.2
A/098		06:46:35	49	11	19	23.6			
A/116		06:50:25	69	10	20	23.3			
A/134		06:54:16	74	10	19	23.2			
A/152		06:58:06	63	9	18	23.1			
A/170		07:01:56	73	8	17	23.5			
A/188		07:05:46	76	9	17	22.5			
A/206		07:09:37	70	7	17	23.7			
A/224		07:13:27	68	9	16	23.9			
A/242		07:17:17	72	9	17	24.2			
A/260		07:21:07	67	9	15	24.5			
B/260	3000'	07:29	45	4	14		38.7	5.1	0.9
B/242		07:31							
B/224		07:34	59	5	14				
B/206		07:39	65	6	16				
B/188		07:43							
B/170		07:47							
B/152		07:51							
B/134		07:55	60	7	13				
B/116		07:59							
B/098		08:03							
B/080		08:07	49	5	14				
C/080	2000'	08:14:12	76	5	12	22.9		3.6	<0.2
C/098		08:19:02	82	6	15	21.9			
C/116		08:23:52	-	4	12	23.0			
C/134		08:28:42	51	4	12	23.3			
C/152		08:33:32	51	6	11	23.5			
C/170		08:38:22	71	4	10	23.4			
C/188		08:43:12	84	6	13	23.7			
C/206		08:50	83	7	15				
C/224		08:54	55	5	11				
C/242		08:59							
C/260		09:04							

* See flight map for Arc; Radial off DFW VOR.

Table A-4. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 8, 1985

Hydrocarbon	A/C Arc A 0658 - 0706 (CDT)	A/C Arc B 0744 - 0752 (CDT)
Ethane	32.0	13.2
Ethylene	(2.7)	(1.1)
Acetylene	2.2	0.8
Propane	14.9	6.2
Propene	1.2	0.1
i-Butane	1.8	0.9
n-Butane	8.3	3.9
i-Pentane	4.9	2.8
n-Pentane	3.2	1.8
Cyclopentane	0.2	0.5
Isoprene	-	0.2
2,3-Dimethylbutane	0.3	-
2-Methylpentane	1.2	0.7
3-Methylpentane	0.7	0.3
n-Hexane	1.1	0.6
Methylcyclopentane	0.7	0.3
Benzene	3.9	1.6
Cyclohexane	0.5	0.1
2-Methylhexane	0.4	-
3-Methylhexane	1.5	0.8
2,2,4-Trimethylpentane	0.4	-
Toluene	2.0	1.4
n-Octane	2.3	-
Ethylbenzene	0.4	0.1
p & *m*-Xylene	1.2	0.2
o-Xylene	0.6	1.1
Total Identified HC	88.6	38.7
TOTAL NMHC	118.0	41.3
% Paraffins	85	83
% Olefins	4	4
% Aromatics	9	11

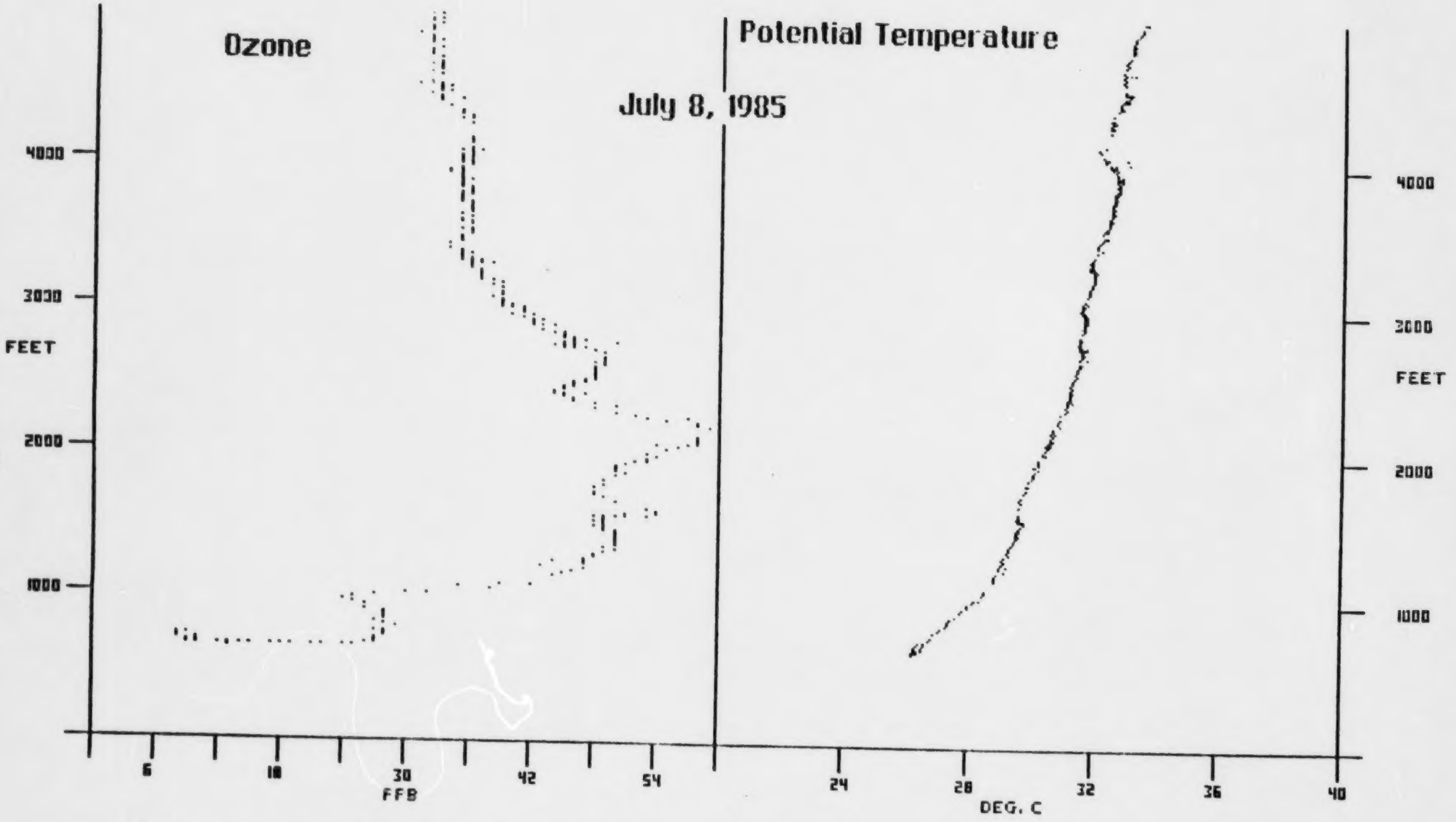


Figure A-8. Potential temperature and ozone changes with altitude on July 8, 1985

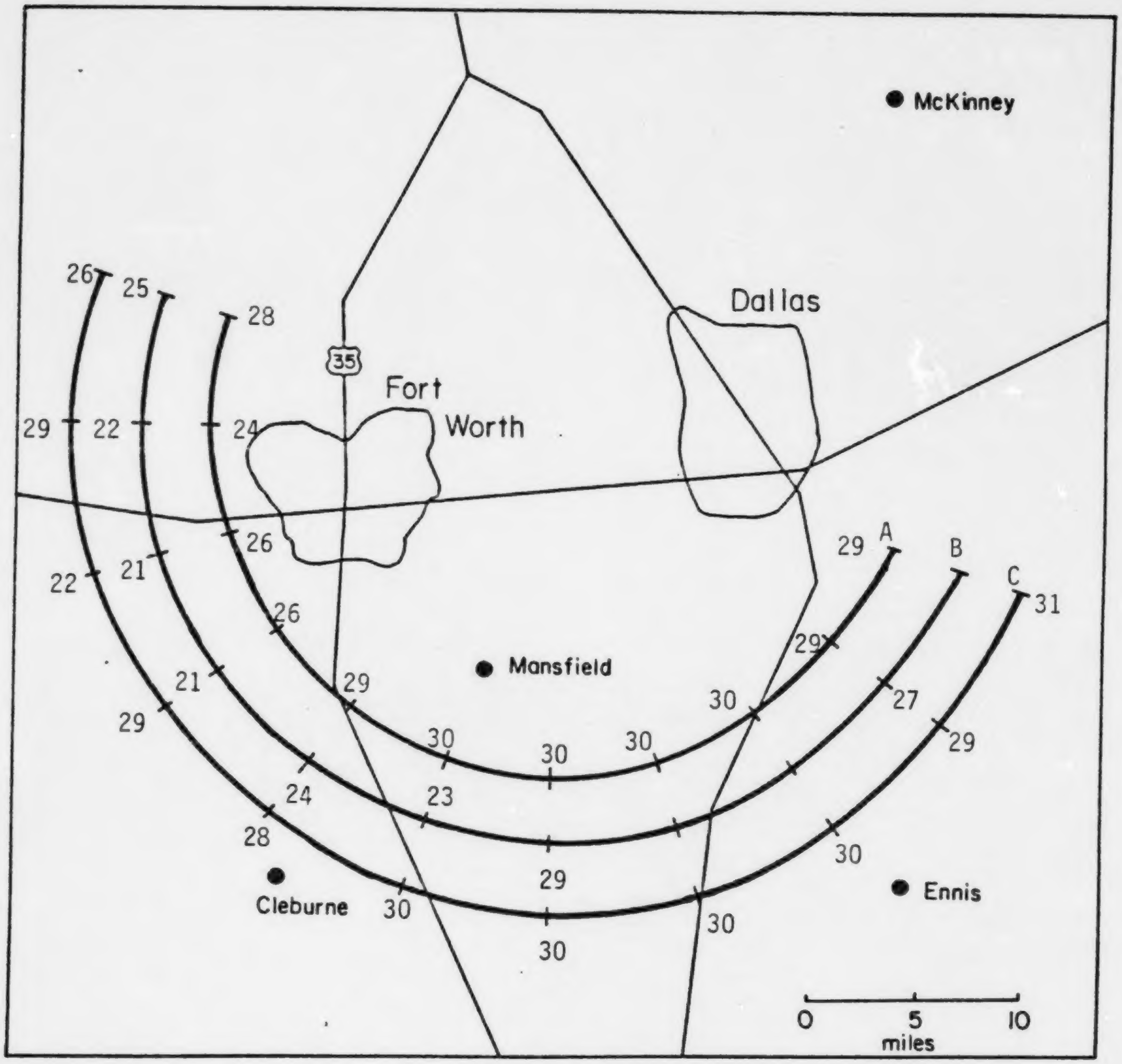

McKinney
Dallas
35
Fort Worth
Mansfield
Cleburne
Ennis
A
B
C
26
25
28
29
22
24
22
21
26
26
29
21
29
30
30
30
30
29
31
27
29
24
23
28
29
30
30
30
30
0
5
10
miles

Figure A-9. July 9 flight path with ozone concentrations (ppb) marked along the route.

Time (CDT) and Altitude (AGL)

A: 0622 - 0700 at 2000'

B: 0705 - 0745 at 3000'

C: 0749 - 0835 at 2000'

Wind: 200° at 18 knots

July 9, 1985

Morning Mixing Level: 900 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/110	2000'	06:22:56	29	5	9	25.2	23.0	0.9	<0.2
A/128		06:26:36	29	6	8	25.0			
A/146		06:31:16	30	5	7	24.7			
A/164		06:34:06	30	5	6	24.5			
A/182		06:37:46	30	5	7	24.8			
A/200		06:41:26	30	4	8	24.9			
A/218		06:45:06	29	7	8	25.1			
A/236		06:48:57	26	6	6	25.7			
A/254		06:52:38	26	6	9	25.6			
A/272		06:56:18	24	6	14	24.9			
A/290		06:59:59	29	5	7	25.0			
B/290	3000'	07:05:16	25	4	5	24.3	6.6	0.5	0.2
B/272		07:09:18	22	5	5	24.3			
B/254		07:13:18	21	5	7	24.3			
B/236		07:17:18	21	5	7	24.2			
B/218		07:21:18	24	3	4	23.9			
B/200		07:25	23	5	9				
B/182		07:30	29	6	7				
B/164		07:34							
B/146		07:38							
B/128		07:41	27	4	6				
B/110		07:45							
C/110	2000'	07:49:15	31	4	7	24.8		1.4	0.3
C/128		07:53:45	29	6	7	25.1			
C/146		07:58:16	30	5	6	25.0			
C/164		08:02:47	30	5	6	24.6			
C/182		08:07:17	30	5	6	24.3			
C/200		08:11:47	30	4	5	24.7			
C/218		08:16:17	28	5	6	24.7			
C/236		08:20:47	29	3	8	24.6			
C/254		08:25:17	22	4	5	25.0			
C/272		08:29:47	29	6	8	25.2			
C/290		08:34:29	26	4	5	25.4			

* See flight map for Arc; Radial off DFW VOR.

Table A-5. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 9, 1985

Hydrocarbon	A/C Arc A 0713 - 0720 (CDT)	A/C Arc B 0738 - 0745 (CDT)
Ethane	4.1	2.7
Ethylene	*	(0.2)
Acetylene	0.7	*
Propane	*	1.3
Propene	0.7	*
i-Butane	*	0.6
n-Butane	2.9	0.7
i-Pentane	1.6	0.1
n-Pentane	1.1	0.1
Cyclopentane	-	-
Isoprene	1.1	-
2,3-Dimethylbutane	-	-
2-Methylpentane	0.5	0.1
3-Methylpentane	0.2	-
n-Hexane	0.4	-
Methylcyclopentane	0.4	-
Benzene	0.8	0.1
Cyclohexane	-	-
2-Methylhexane	0.4	-
3-Methylhexane	0.4	-
2,2,4-Trimethylpentane	0.2	
Toluene	1.8	0.7
n-Octane	2.7	-
Ethylbenzene	2.1	-
p & *m*-Xylene	0.7	-
o-Xylene	0.2	-
Total Identified HC	23.0	6.6
TOTAL NMHC	42.8	7.7
% Paraffins	71	85
% Olefins	6	3
% Aromatics	20	12

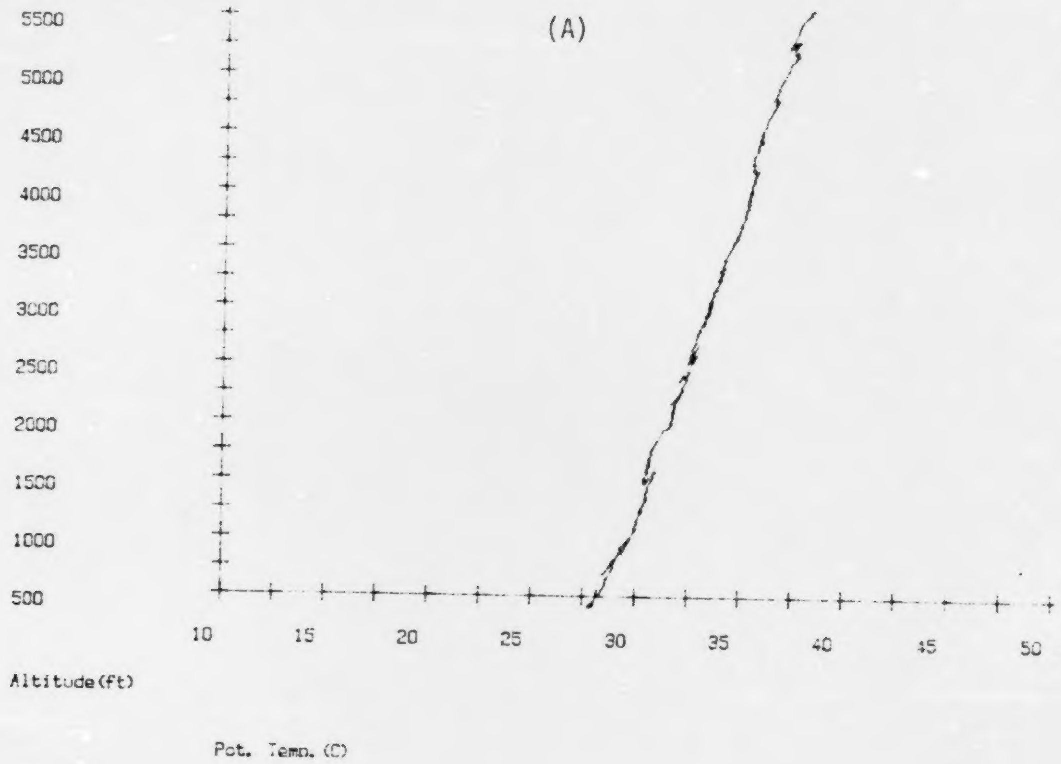
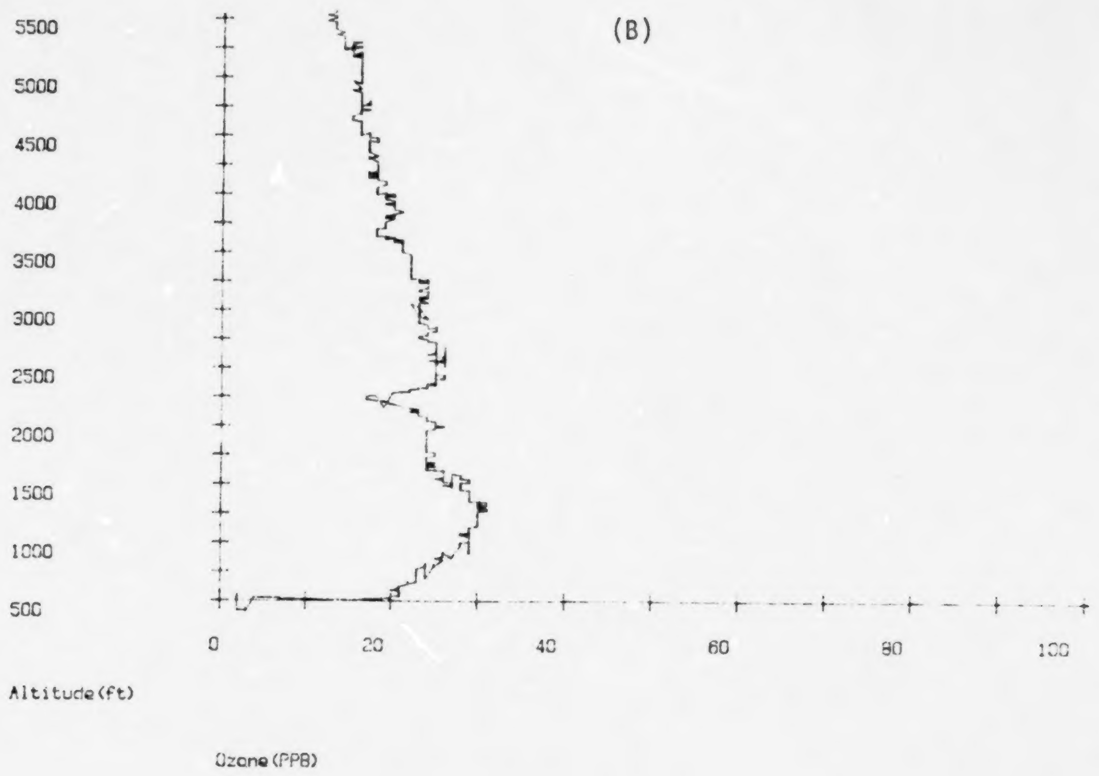
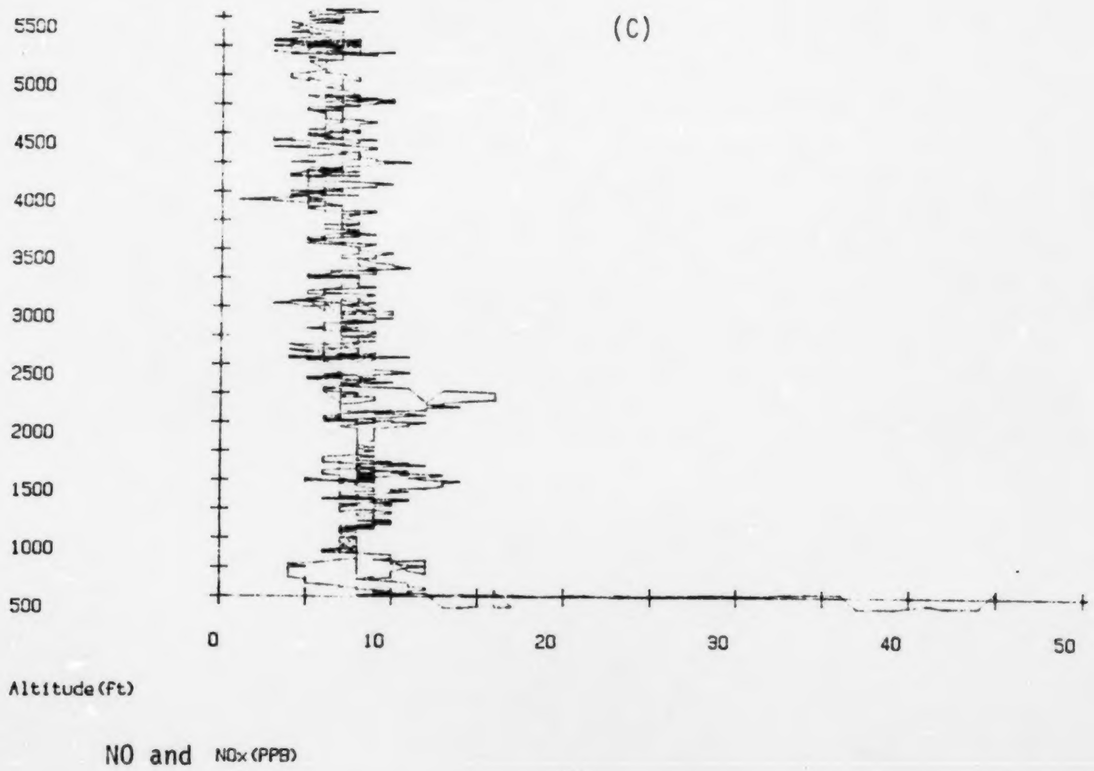
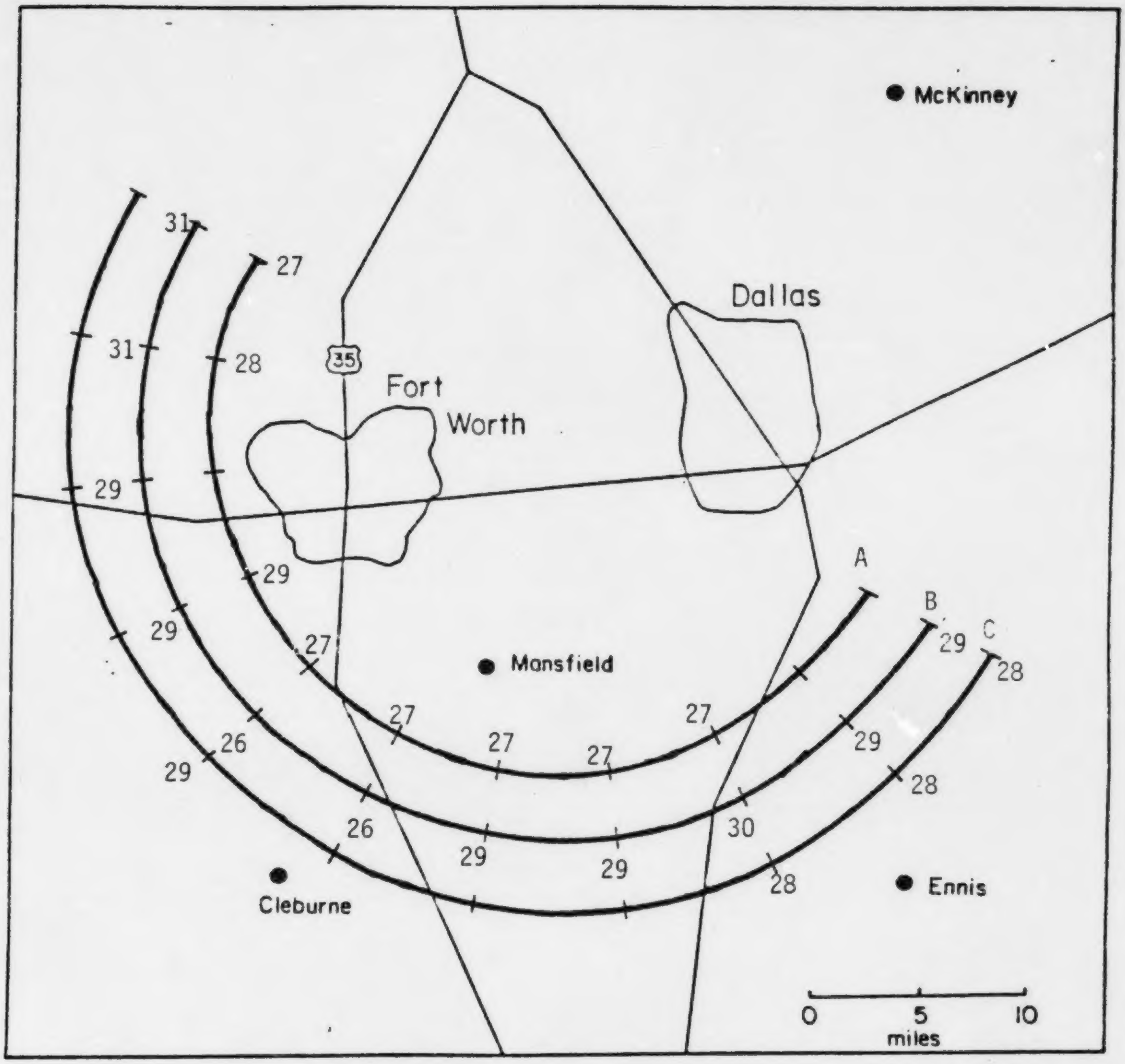


Figure A-10. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on July 9, 1985.

(Figure A-10. cont'd.)






McKinney
Dallas
35
Fort Worth
Mansfield
Cleburne
Ennis
A
B
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31
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29
27
29
26
27
27
27
27
26
29
29
30
29
28
29
28
28
0
5
10
miles

Figure A-11. July 10 flight path with ozone concentrations (ppb) marked along the route.

Time (CDT) and Altitude (AGL)

A: 0633 - 0713 at 2000'

B: 0717 - 0758 at 3000'

C: 0808 - 0856 at 2000'

Wind: 210° at 12 knots

July 10, 1985

Morning Mixing Level: 1100 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/120		06:33							
A/138		06:37							
A/156		06:41:01	27	6	8	27.7			
A/174		06:45:01	27	7	8	27.3			
A/192		06:49:02	27	7	7	27.7			
A/210	2000'	06:53:02	27	5	6	27.5	26.3	2.2	<0.2
A/228		06:57:03	27	4	5	28.2			
A/246		07:01:03	29	7	7	28.6			
A/264		07:04:53		6	6	28.6			
A/282		07:08:53	28	6	6	28.3			
A/300		07:12:54	27	7	7	28.3			
B/300		07:17:47	31	4	6	26.0			
B/282		07:21:48	31	4	6	25.9			
B/264		07:25:48	29	5	5	26.1			
B/246		07:29:49	29	4	5	26.1			
B/228		07:33:49	26	4	6	25.6			
B/210	3000'	07:37:49	26	3	7	25.3	10.2	2.0	<0.2
B/192		07:41:49	29	4	7	25.1			
B/174		07:45:49	29	5	5	25.0			
B/156		07:48:49	30	3	5	24.8			
B/138		07:53:49	29	5	5	24.7			
B/120		07:57:50	29	5	6	24.5			
C/120		08:08:17	28	4	6	27.3			
C/138		08:13:08	28	4	6	27.3			
C/156		08:17:48	28	6	5	27.0			
C/174		08:22							
C/192		08:26							
C/210	2000'	08:31					30.1	1.8	<0.2
C/228		08:36	29	5	6				
C/246		08:40							
C/264		08:45							
C/282		08:49							
C/300									

* See flight map for Arc; Radial off DFW VOR.

Table A-6. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 10, 1985

Hydrocarbon	A/C Arc A 0650 - 0657 (CDT)	A/C Arc B 0735 - 0742 (CDT)	A/C Arc C 0824 - 0831 (CDT)
Ethane	2.8	2.8	2.8
Ethylene	(0.6)	(0.4)	(0.4)
Acetylene	-	0.1	0.1
Propane	3.2	2.0	2.0
Propene	-	0.2	0.7
i-Butane	-	1.1	1.1
n-Butane	1.6	1.0	1.1
i-Pentane	0.7	0.6	0.6
n-Pentane	1.6	0.6	0.6
Cyclopentane	-	-	-
Isoprene	1.6	0.7	0.8
2,3-Dimethylbutane	-	-	0.1
2-Methylpentane	0.6	0.2	0.2
3-Methylpentane	0.3	-	-
n-Hexane	0.7	-	0.2
Methylcyclopentane	0.3	-	0.1
Benzene	0.4	0.2	0.6
Cyclohexane	-	-	0.2
2-Methylhexane	0.7	-	0.4
3-Methylhexane	-	-	-
2,2,4-Trimethylpentane	-	-	0.1
Toluene	4.0	0.3	2.1
n-Octane	-	-	0.6
Ethylbenzene	1.9	-	4.3
p & m-Xylene	4.2	-	6.8
o-Xylene	1.1	-	4.2
Total Identified HC	26.3	10.2	30.1
TOTAL NMHC	33.2	10.2	103.0
% Paraffins	48	82	34
% Olefins	8	12	6
% Aromatics	44	5	60

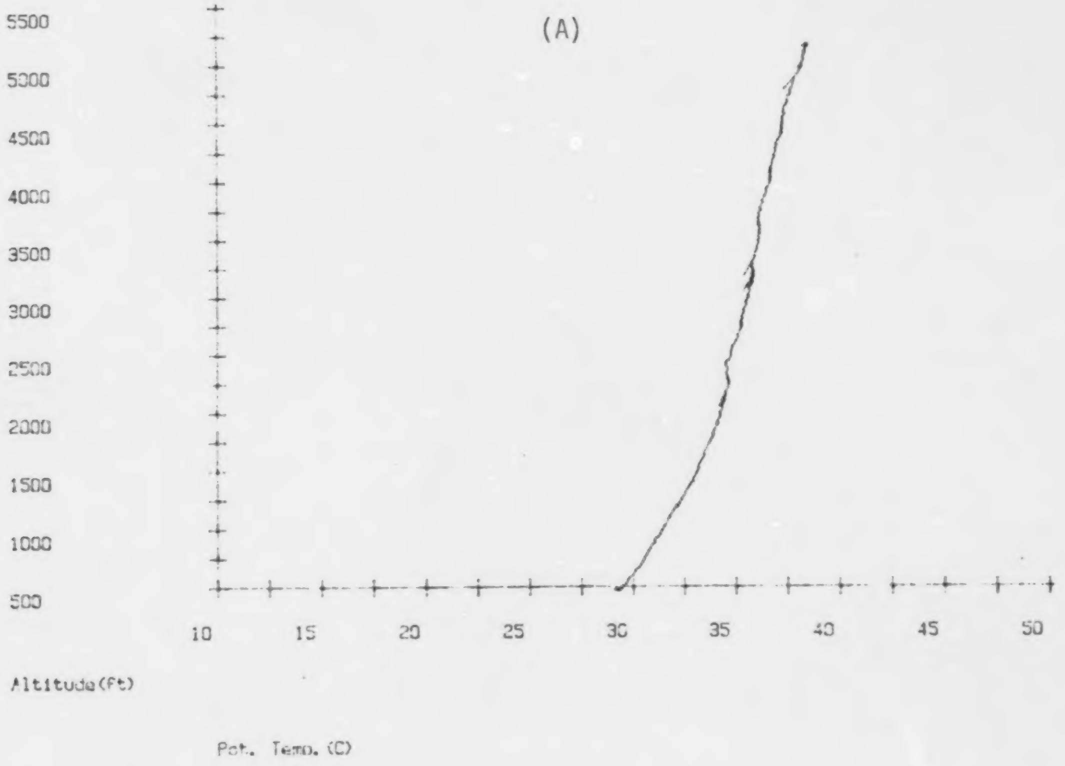
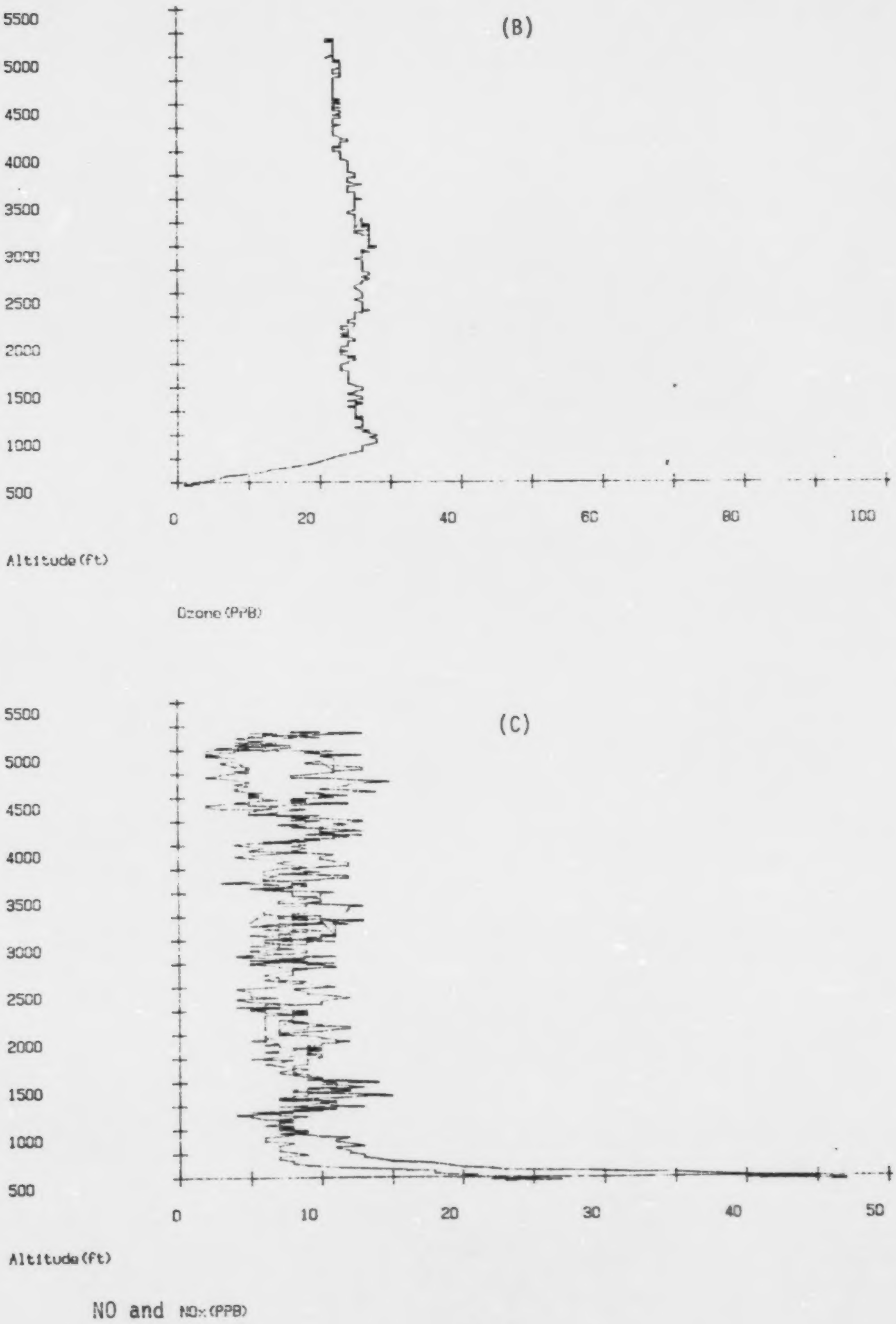
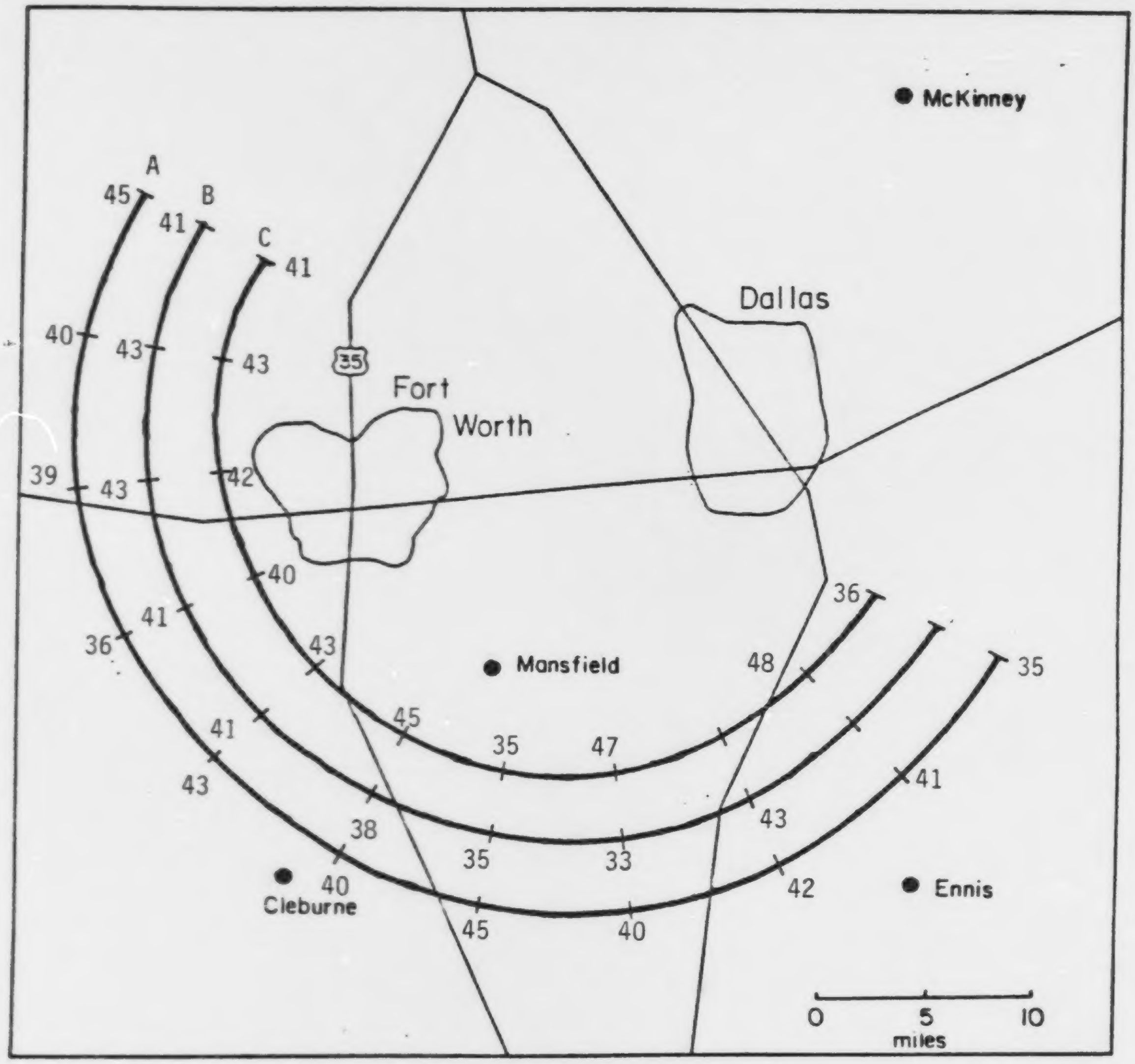


Figure A-12. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on July 10, 1985.

(Figure A-12. cont'd.)

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Mansfield
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45
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47
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41
38
35
33
43
40
Cleburne
42
Ennis
45
40
0
5
10
miles

Figure A-13. July 11 flight path with ozone concentrations (ppb) marked along the route.

Time (CDT) and Altitude (AGL)

A: 0623 - 0709 at 2000'

B: 0714 - 0750 at 3000'

C: 0756 - 0834 at 2000'

Wind: light and variable

July 11, 1985

Morning Mixing Level: 820 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/120	2000'	06:23:47	35	7	7	27.2	18.2	3.7	0.2
A/138		06:28:18	41	7	8	26.7			
A/156		06:32:49	42	7	10	27.1			
A/174		06:37:20	40	8	8	27.0			
A/192		06:41:50	45	6	8	26.8			
A/210		06:46:20	40	4	8	27.2			
A/228		06:50:52	43	8	8	27.1			
A/246		06:55:22	36	5	7	27.6			
A/264		06:59:52	39	5	6	27.9			
A/282		07:04:23	40	3	7	28.0			
A/300		07:08:53	45	7	7	28.0			
B/300	3000'	07:14:14	41	5	5	25.2	12.4	<2.0	<0.2
B/282		07:18:14	43	5	8	25.0			
B/264		07:22:26	43	5	6	24.7			
B/246		07:26:26	41	3	8	24.7			
B/228		07:30:36	41	4	6	24.5			
B/210		07:34:36	38	4	4	24.2			
B/192		07:38:36	35	6	6	24.8			
B/174		07:42:46	33	3	5	24.9			
B/156		07:46:46	43	4	10	24.3			
B/138		07:50							
B/120		07:53							
C/120	2000'	07:56:59	36	5	7	25.6	22.5	0.8	<0.2
C/138		08:00:40	48	7	8	25.6			
C/156		08:04:20	-	4	7	24.5			
C/174		08:08:00	47	8	8	25.8			
C/192		08:11:40	35	5	7	26.6			
C/210		08:15:20	45	5	7	27.3			
C/228		08:19:00	43	6	7	27.8			
C/246		08:22:41	40	6	6	28.1			
C/264		08:26:21	42	6	8	28.3			
C/282		08:30:01	43	7	7	28.5			
C/300		08:33:43	41	5	7	28.9			

* See flight map for Arc; Radial off DFW VOR.

Table A-7. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 11, 1985

Hydrocarbon	A/C Arc A 0640 - 0647 (CDT)	A/C Arc B 0730 - 0739 (CDT)	A/C Arc C 0812 - 0820 (CDT)
Ethane	3.0	3.3	3.3
Ethylene	(0.4)	(0.3)	(0.4)
Acetylene	0.4	0.2	0.7
Propane	2.4	1.6	2.2
Propene	0.5	0.2	4.0
i-Butane	1.5	1.6	1.6
n-Butane	3.1	1.4	1.7
i-Pentane	2.1	1.0	1.2
n-Pentane	1.6	0.6	0.6
Cyclopentane	0.3	-	-
Isoprene	-	0.2	-
2,3-Dimethylbutane	-	-	-
2-Methylpentane	0.3	0.2	0.4
3-Methylpentane	0.2	-	0.1
n-Hexane	0.1	0.2	0.3
Methylcyclopentane	0.1	-	-
Benzene	0.5	0.5	1.4
Cyclohexane	-	-	-
2-Methylhexane	-	-	0.1
3-Methylhexane	-	0.2	0.5
2,2,4-Trimethylpentane	-	-	-
Toluene	0.7	0.5	1.7
n-Octane	-	-	1.1
Ethylbenzene	0.2	-	0.1
p & *m*-Xylene	0.2	0.2	0.5
o-Xylene	0.6	0.2	0.6
Total Identified HC	18.2	12.4	22.5
TOTAL NMHC	21.0	13.8	29.6
% Paraffins	81	84	58
% Olefins	5	5	20
% Aromatics	12	10	19

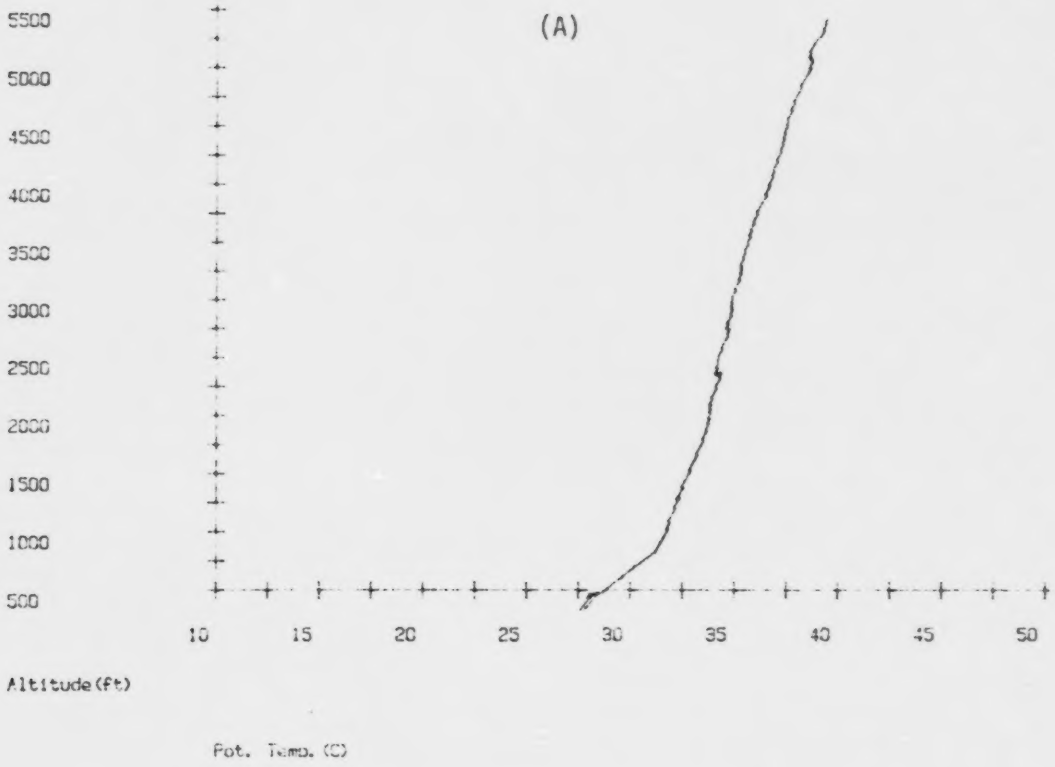
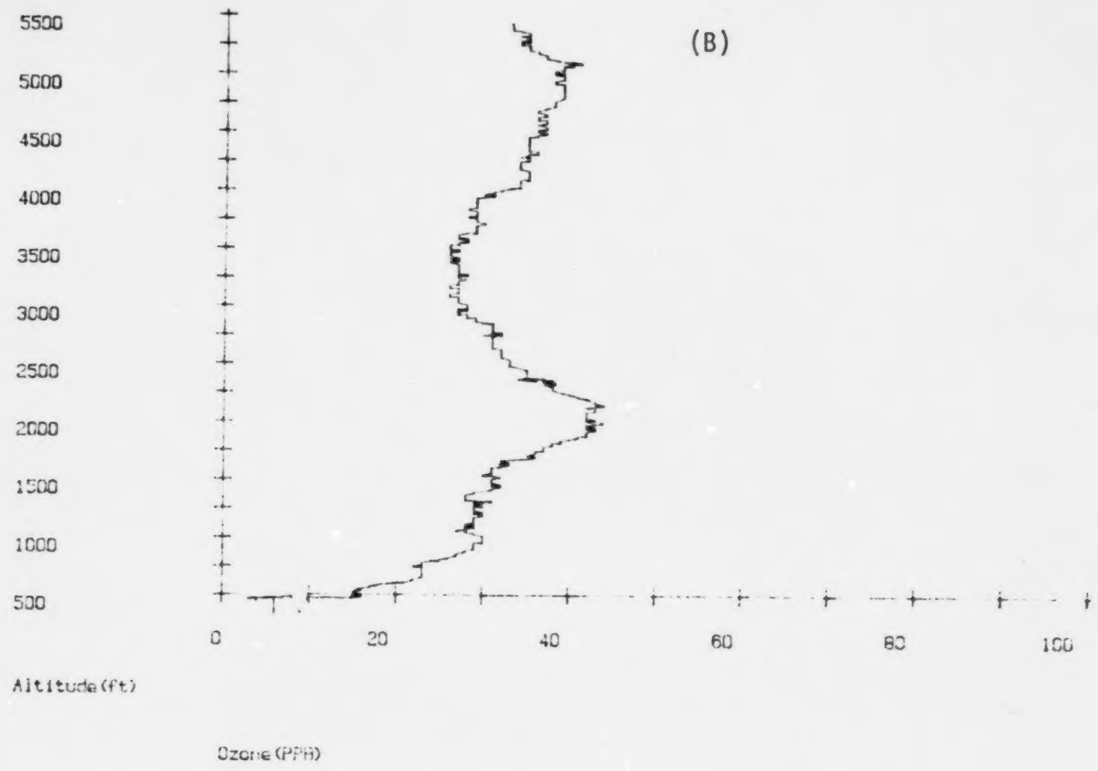
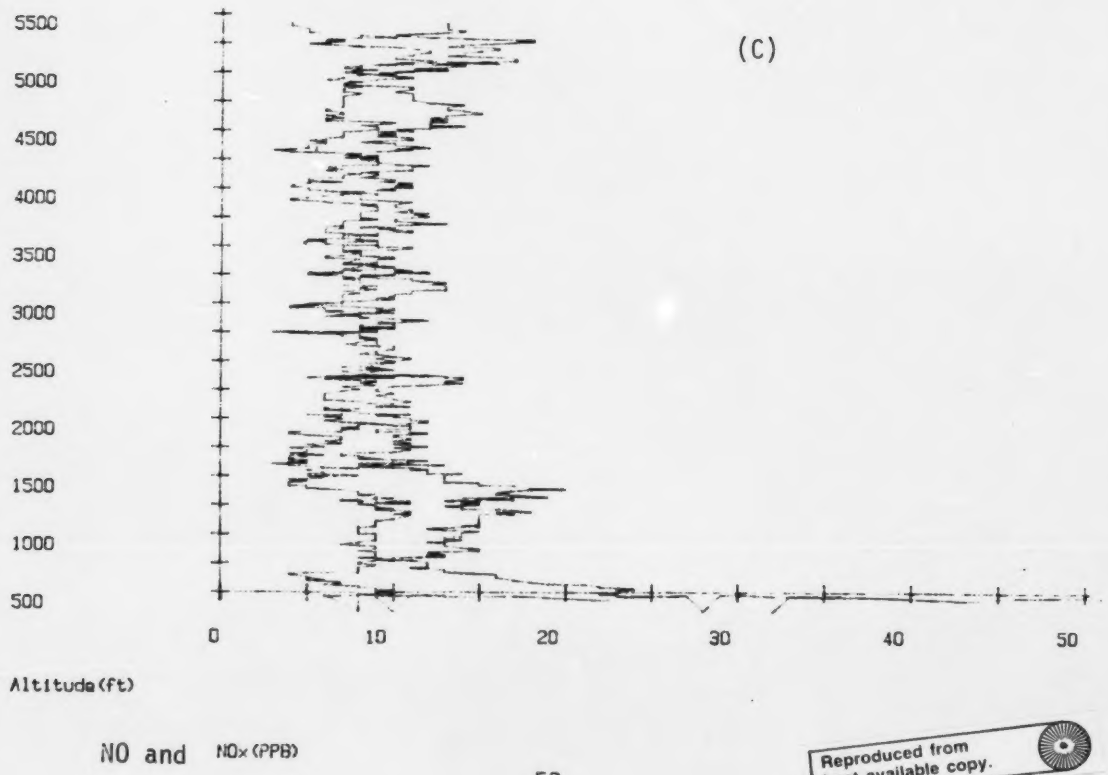


Figure A-14. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on July 11, 1985.

(Figure A-14. cont'd.)





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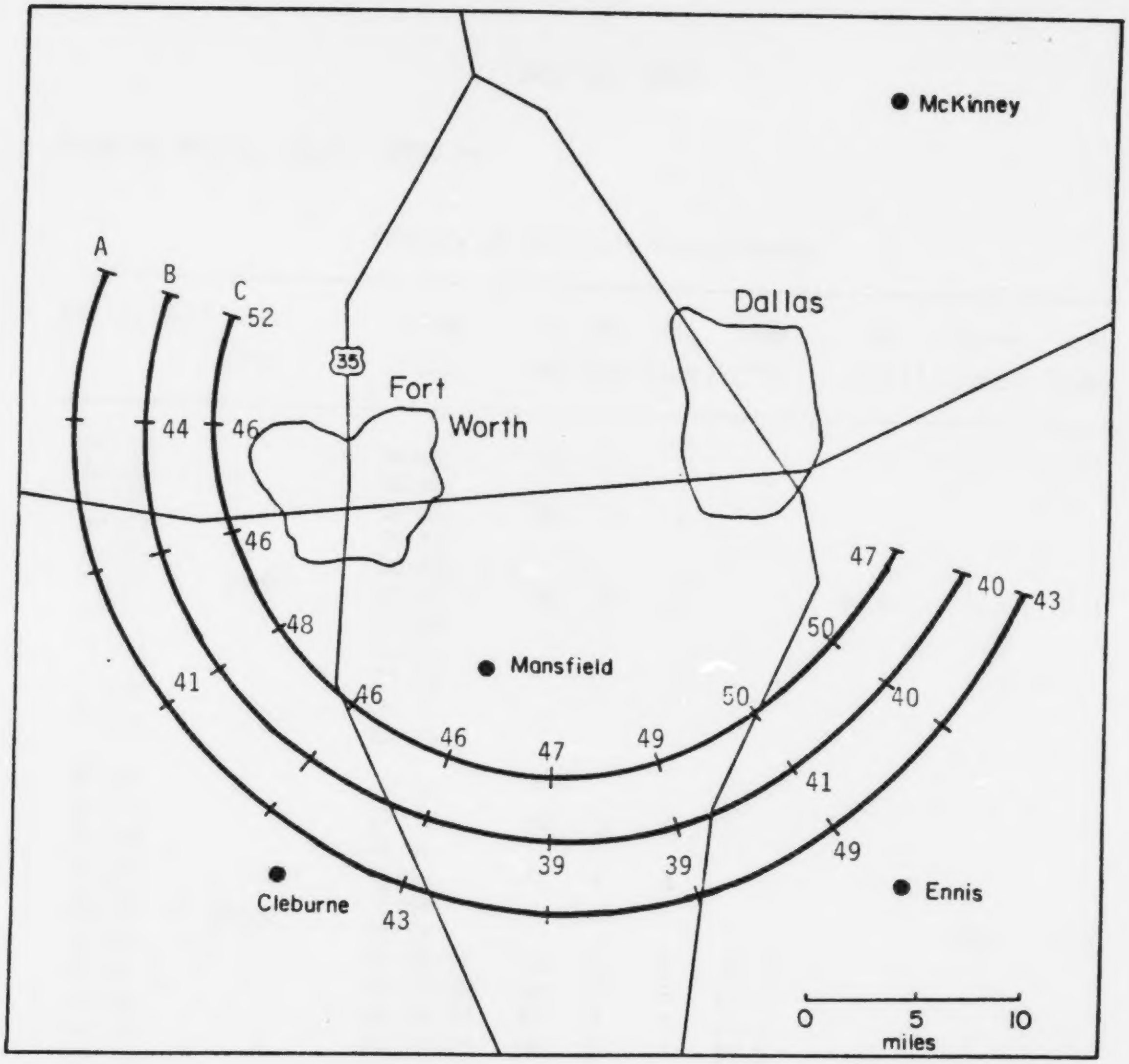
McKinney
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43
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49
Cleburne
43
Ennis
0
5
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miles

Figure A-15. July 12 flight path with ozone concentrations (ppb) marked along the route.

Time (CDT) and Altitude (AGL)

A: 0641 - 0725 at 2000'

B: 0731 - 0813 at 3000'

C: 0818 - 0856 at 2000'

Wind: 200° at 7 knots

July 12, 1985

Morning Mixing Level: 1200 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/110		06:42	43	7	7				
A/128		06:45							
A/146		06:48	49	7	8				
A/164		06:52							
A/182		06:56							
A/200	2000'	07:01	43	6	7		14.8	1.1	<0.1
A/218		07:06							
A/236		07:11							
A/254		07:16							
A/272		07:20							
A/290		07:24							
B/290		07:30							
B/272		07:34	44	5	6				
B/254		07:38							
B/236		07:42	41	4	4				
B/218		07:46							
B/200	3000'	07:51						2.1	0.2
B/182		07:55:58	39	5	5	23.0			
B/164		08:00:08	39	4	5	22.9			
B/146		08:04:09	41	4	5	23.4			
B/128		08:08:19	40	3	4	22.6			
B/110		08:12:19	40	4	5	23.2			
C/110		08:17:18	47	4	4	24.7			
C/128		08:21:08	50	6	8	24.7			
C/146		08:24:58	50	6	7	24.4			
C/164		08:28:48	49	5	6	24.8			
C/182		08:32:28	47	4	8	24.6			
C/200	2000'	08:36:28	46	4	8	24.3	16.1	1.3	<0.2
C/218		08:40:08	46	2	5	24.0			
C/236		08:43:58	48	5	6	25.7			
C/254		08:47:49	46	6	7	26.1			
C/272		08:51:39	46	5	5	26.8			
C/290		08:55:29	52	5	5	25.8			

* See flight map for Arc; Radial off DFW VOR.

Table A-8. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 12, 1985

Hydrocarbon	A/C Arc A 0657 - 0706 (CDT)	A/C Arc C 0834 - 0843 (CDT)
Ethane	4.5	5.4
Ethylene	(0.5)	(0.5)
Acetylene	0.2	0.3
Propane	2.9	3.0
Propene	0.2	0.5
i-Butane	0.7	0.9
n-Butane	1.4	1.7
i-Pentane	0.7	0.7
n-Pentane	0.6	0.6
Cyclopentane	-	-
Isoprene	-	-
2,3-Dimethylbutane	-	-
2-Methylpentane	0.1	0.2
3-Methylpentane	-	-
n-Hexane	0.1	0.2
Methylcyclopentane	-	-
Benzene	0.6	0.6
Cyclohexane	-	-
2-Methylhexane	-	-
3-Methylhexane	0.5	0.5
2,2,4-Trimethylpentane	-	-
Toluene	1.0	0.6
n-Octane	-	-
Ethylbenzene	-	-
p & *m*-Xylene	0.1	-
o-Xylene	0.7	0.4
Total Identified HC	14.8	16.1
TOTAL NMHC	16.8	17.4
% Paraffins	78	82
% Olefins	5	6
% Aromatics	16	10

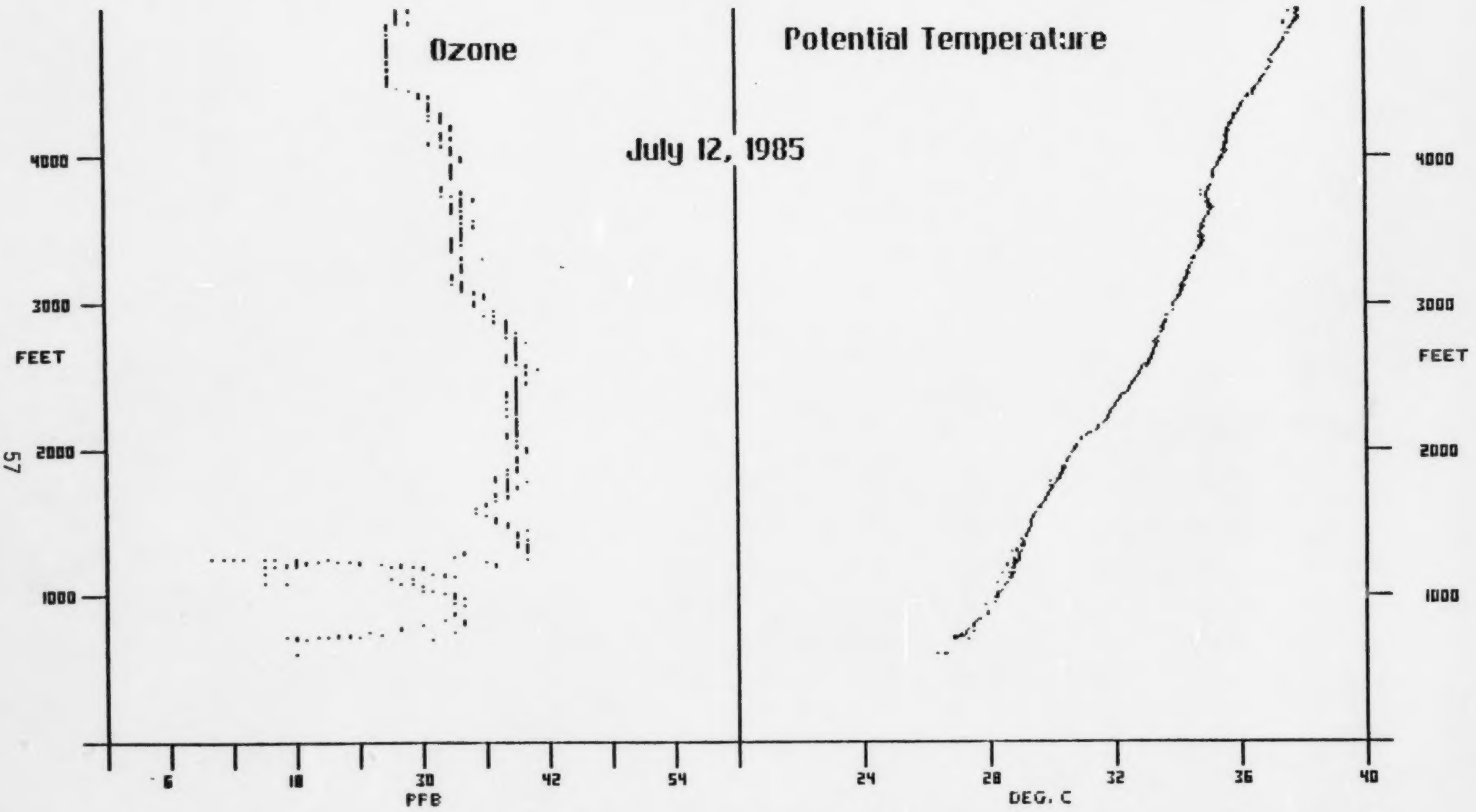
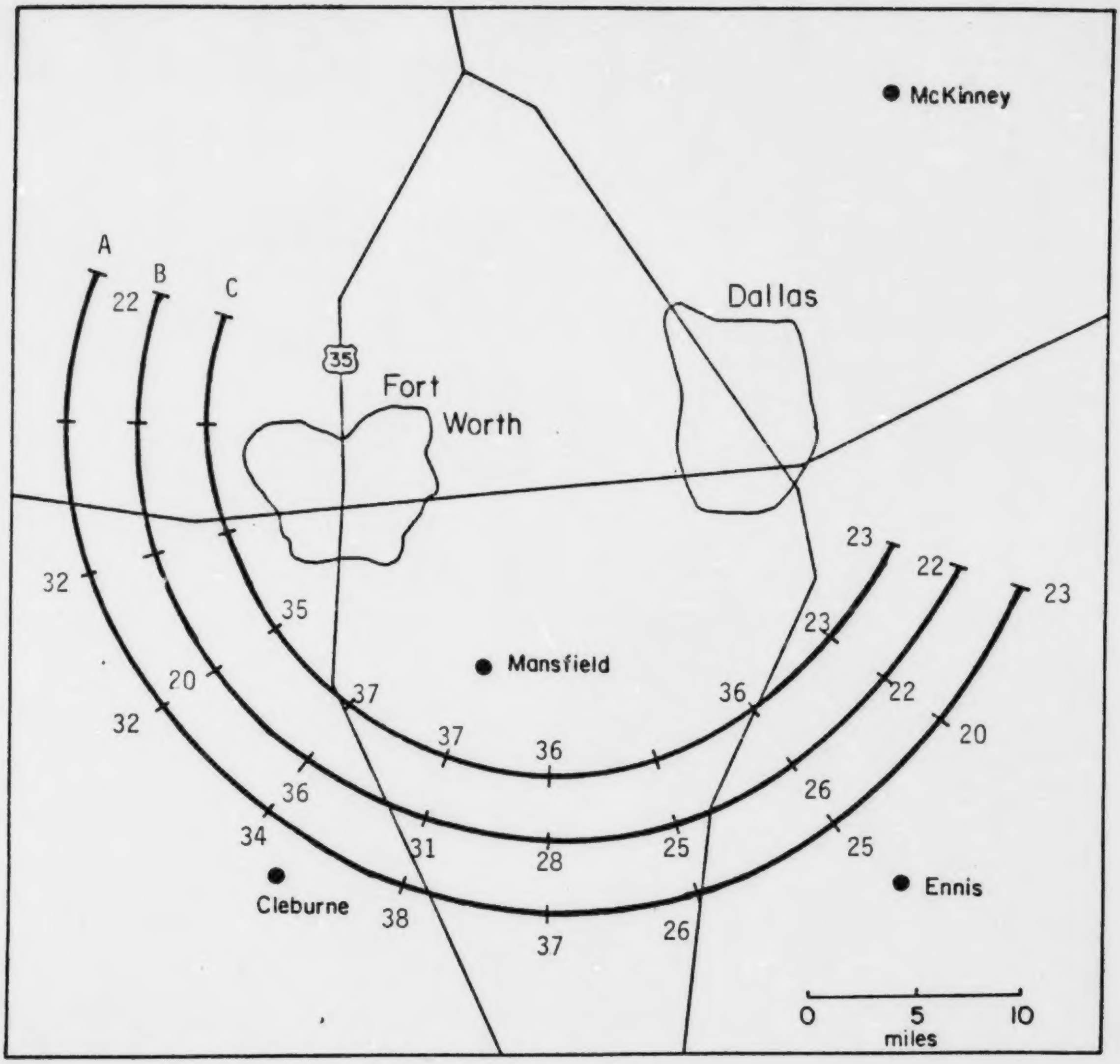


Figure A-16. Potential temperature and ozone changes with altitude on July 12, 1985


McKinney
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Dallas
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Fort Worth
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Mansfield
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20
32
37
36
36
26
36
34
31
28
25
25
Cleburne
38
37
26
Ennis
0
5
10
miles

Figure A-17. July 13 flight path with ozone concentrations (ppb) marked along the route.

Time (CDT) and Altitude (AGL)

A: 0630 - 0710 at 2000'

B: 0718 - 0758 at 3000'

C: 0802 - 0840 at 2000'

Wind: 200° at 15 knots

July 13, 1985

Morning Mixing Level: 1150 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/110	2000'	06:30:15	23	7	7	25.6	15.8	1.6	0.2
A/128		06:34:36	20	6	6	24.9			
A/146		06:38:56	25	6	9	24.7			
A/164		06:43:06	26	5	5	24.4			
A/182		06:47:26	37	7	8	24.2			
A/200		06:51:46	38	4	7	24.6			
A/218		06:56:07	34	4	10	24.6			
A/236		07:00:17	32	5	8	24.5			
A/254		07:04:37	32	7	7	24.6			
A/272		07:08							
A/290		07:12							
B/290	3000'	07:20	22	6	6		16.3	0.8	1.0
B/272		07:24							
B/254		07:27							
B/236		07:30:24	20	7	6	23.5			
B/218		07:34:04	26	5	7	23.3			
B/200		07:37:54	31	7	8	22.8			
B/182		07:41:44	28	4	8	22.9			
B/164		07:45:34	25	4	6	23.0			
B/146		07:49:25	26	4	4	23.0			
B/128		07:53:16	22	6	6	23.3			
B/110		07:57:07	22	5	5	23.3			
C/110	2000'	08:02:52	23	6	6	25.1	20.9	2.2	<0.2
C/128		08:05	23	7	7				
C/146		08:11	36	5	9				
C/164		08:14							
C/182		08:17:44	36	6	7	25.0			
C/200		08:21:24	37	5	6	25.1			
C/218		08:25:04	37	6	7	25.2			
C/236		08:28:44	35	5	5	25.4			
C/254		08:32							
C/272		08:35							
C/290		08:39							

* See flight map for Arc; Radial off DFW VOR.

Table A-9. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 13, 1985

Hydrocarbon	A/C Arc A 0646 - 0653 (CDT)	A/C Arc B 0735 - 0744 (CDT)	A/C Arc C 0818 - 0827 (CDT)
Ethane	5.0	4.2	5.7
Ethylene	(0.5)	(0.2)	(0.7)
Acetylene	0.2	0.2	*
Propane	2.7	1.4	3.7
Propene	0.2	0.4	*
i-Butane	1.0	1.5	2.7
n-Butane	1.4	1.8	2.0
i-Pentane	0.9	1.3	1.4
n-Pentane	0.6	-	0.8
Cyclopentane	0.1	-	-
Isoprene	-	0.8	-
2,3-Dimethylbutane	-	0.1	0.1
2-Methylpentane	0.2	0.3	0.4
3-Methylpentane	-	0.2	0.2
n-Hexane	0.3	0.3	0.4
Methylcyclopentane	0.2	0.2	-
Benzene	0.6	1.3	1.3
Cyclohexane	-	-	0.2
2-Methylhexane	0.2	0.2	0.1
3-Methylhexane	0.4	0.9	-
2,2,4-Trimethylpentane	-	0.2	0.1
Toluene	0.4	0.8	0.7
n-Octane	-	-	-
Ethylbenzene	-	*	0.1
p & *m*-Xylene	-	*	0.2
o-Xylene	0.9	*	0.1
Total Identified HC	15.8	16.3	20.9
TOTAL NMHC	17.8	21.8	25.0
% Paraffins	83	77	85
% Olefins	4	9	3
% Aromatics	12	13	12

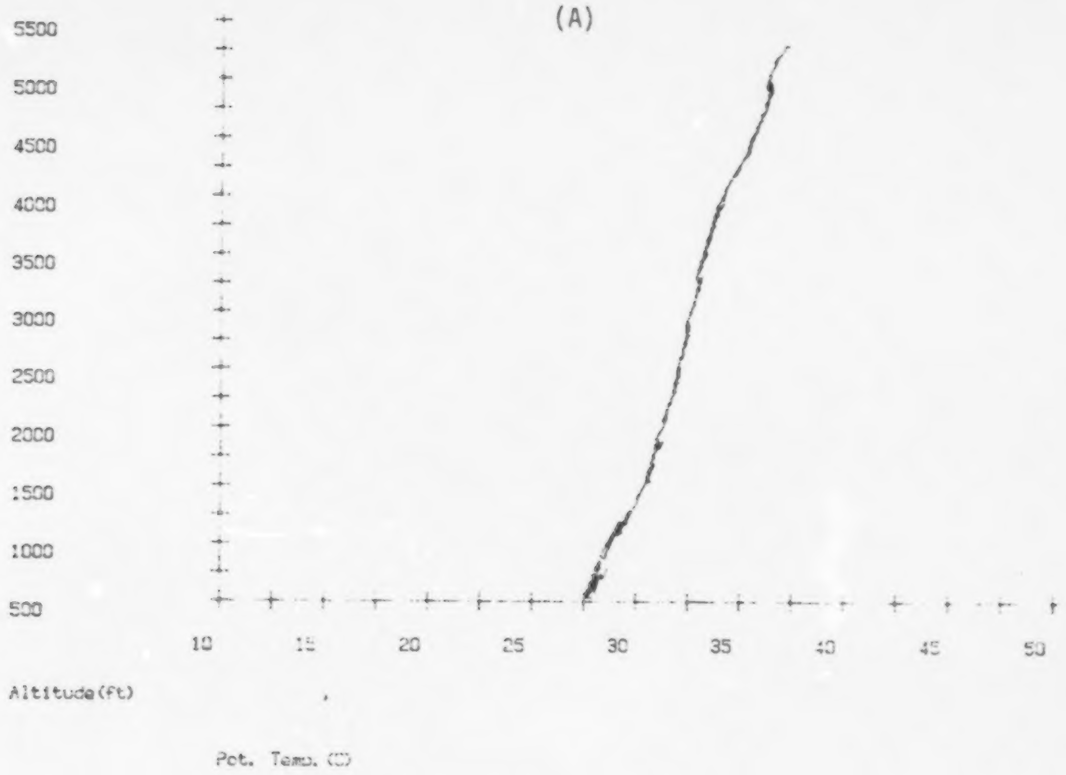
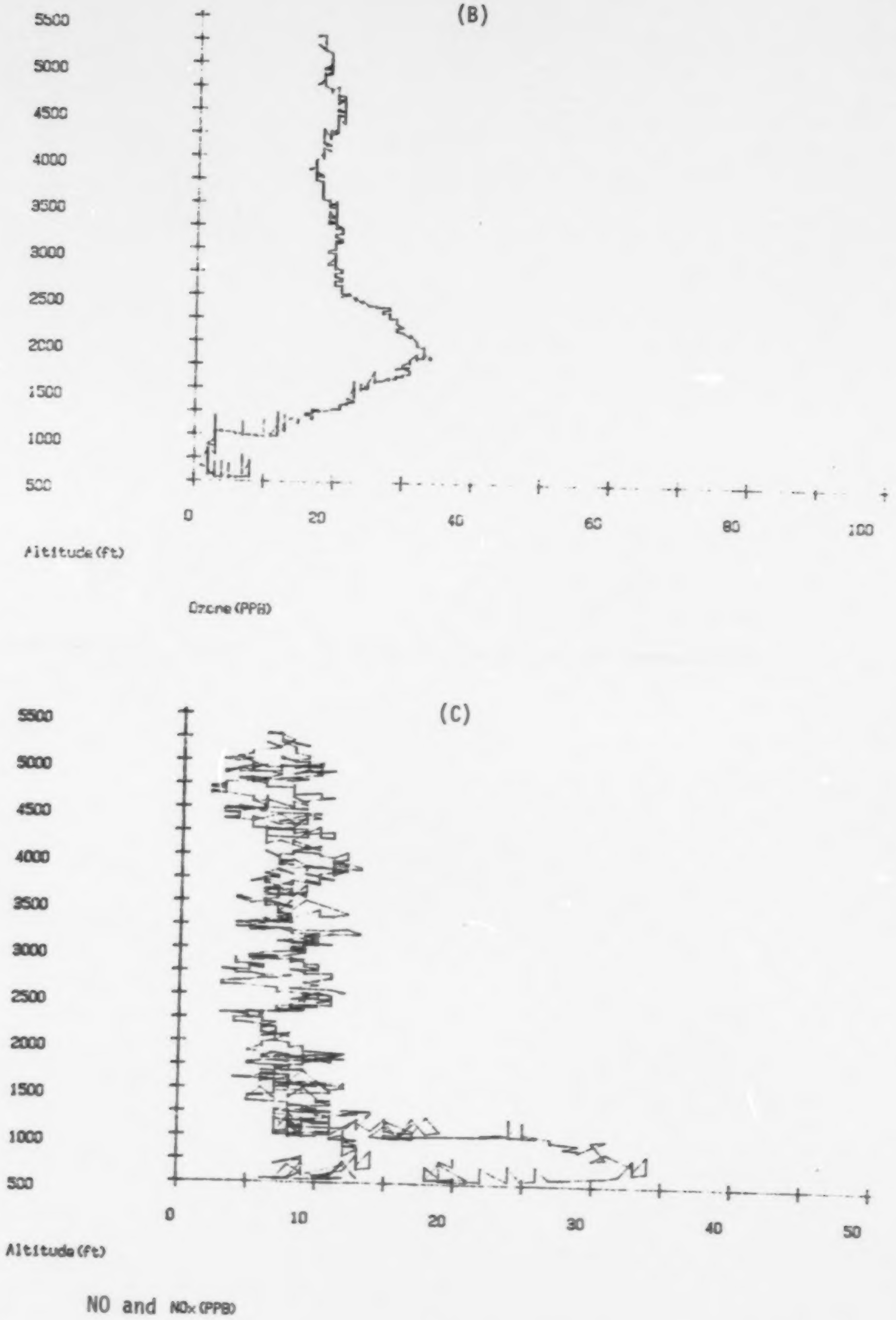
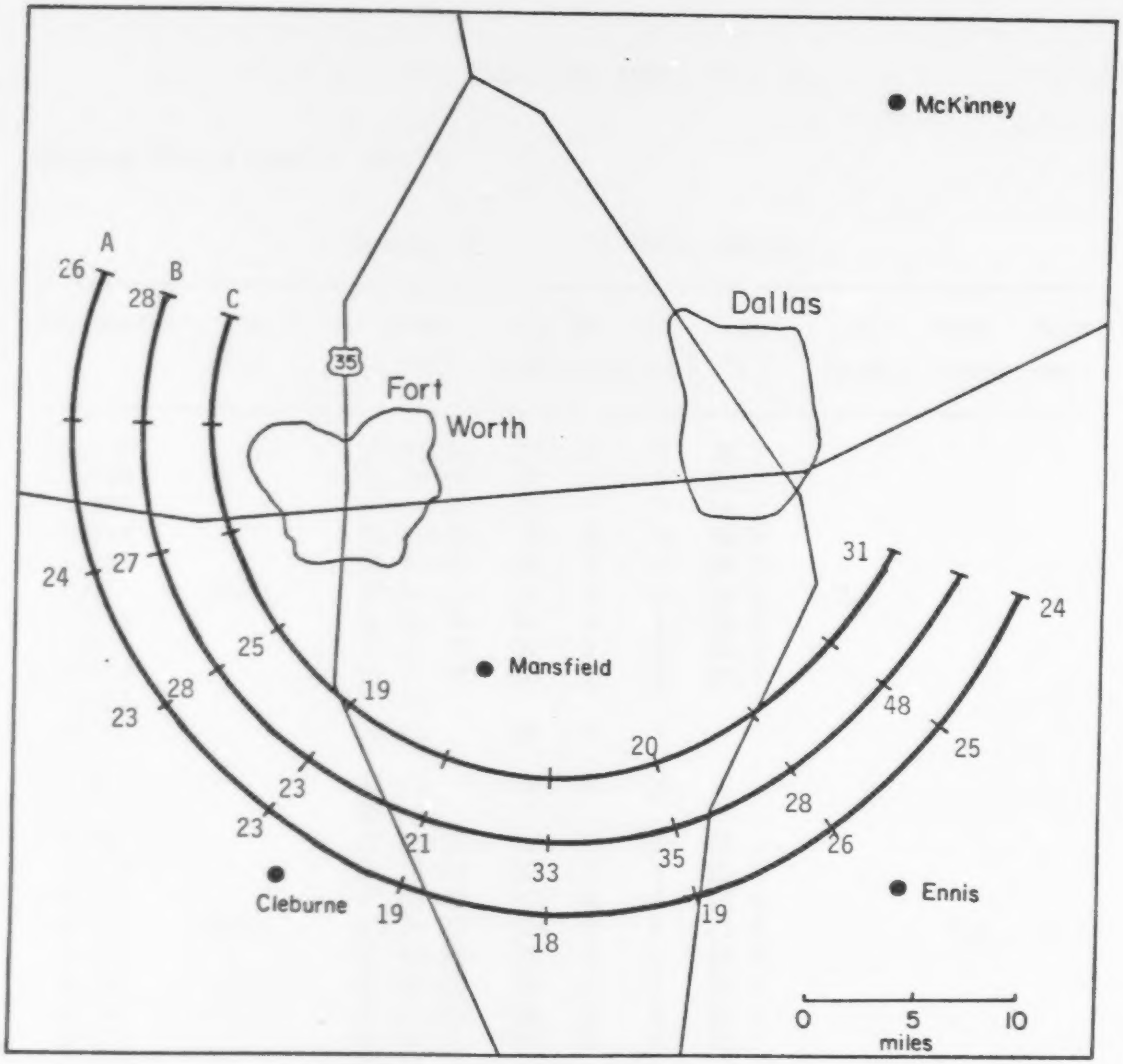


Figure A-18. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on July 13, 1985.

(Figure A-18. cont'd.)




McKinney
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Dallas
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Mansfield
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23
28
20
25
23
28
23
21
26
33
35
Cleburne
19
18
19
Ennis
0
5
10
miles

Figure A-19. July 14 flight path with ozone concentrations (ppb) marked along the route.

Time (CDT) and Altitude (AGL)

A: 0631 - 0712 at 2000'

B: 0718 - 0757 at 3000'

C: 0800 - 0834 at 2000'

Wind: 200° at 12 knots

July 14, 1985

Morning Mixing Level: 980 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/110	2000'	06:31:56	24	9	9	24.2	3.8	0.1	<0.2
A/128		06:35:56	25	3	6	24.2			
A/146		06:40:06	26	7	7	24.2			
A/164		06:44:15	19	5	8	24.4			
A/182		06:48:26	18	4	5	24.3			
A/200		06:52:26	19	5	6	24.2			
A/218		06:56:36	23	5	6	24.8			
A/236		07:00:47	23	6	6	24.9			
A/254		07:04:48	24	5	5	24.7			
A/272		07:07							
A/290		07:11	26	5	7				
B/290	3000'	07:19	28	5	6			0.3	<0.2
B/272		07:23							
B/254		07:26:09	27	3	5	22.5			
B/236		07:29:59	28	5	6	22.8			
B/218		07:33:49	23	4	6	22.9			
B/200		07:37:39	21	3	5	23.0			
B/182		07:41:29	33	3	5	22.9			
B/164		07:45:19	35	4	7	22.0			
B/146		07:49:09	28	4	6	22.0			
B/128		07:53:01	48	3	6	22.1			
B/110		07:57							
C/110	2000'	08:01	31	5	7		4.7	0.7	0.5
C/128		08:04							
C/146		08:07							
C/164		08:10	20	4	4				
C/182		08:13							
C/200		08:16							
C/218		08:19	19	2	6				
C/236		08:25	25	5	5				
C/254		08:29							
C/272		08:34							
C/290		08:38							

* See flight map for Arc; Radial off DFW VOR.

Table A-10. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 14, 1985

Hydrocarbon	A/C Arc A 0647 - 0657 (CDT)	A/C Arc C 0816 - 0825 (CDT)
Ethane	1.6	1.1
Ethylene	(0.1)	-
Acetylene	0.2	0.1
Propane	0.6	0.3
Propene	0.1	0.1
i-Butane	0.2	0.1
n-Butane	0.3	0.1
i-Pentane	-	0.2
n-Pentane	-	-
Cyclopentane	-	-
Isoprene	-	-
2,3-Dimethylbutane	-	-
2-Methylpentane	-	-
3-Methylpentane	-	-
n-Hexane	-	-
Methylcyclopentane	-	-
Benzene	0.3	0.3
Cyclohexane	-	-
2-Methylhexane	-	-
3-Methylhexane	-	0.7
2,2,4-Trimethylpentane	-	-
Toluene	0.4	0.5
n-Octane	-	-
Ethylbenzene	-	0.5
p & *m*-Xylene	-	0.2
o-Xylene	-	0.5
Total Identified HC	3.8	4.7
TOTAL NMHC	5.8	6.9
% Paraffins	72	53
% Olefins	5	2
% Aromatics	18	43

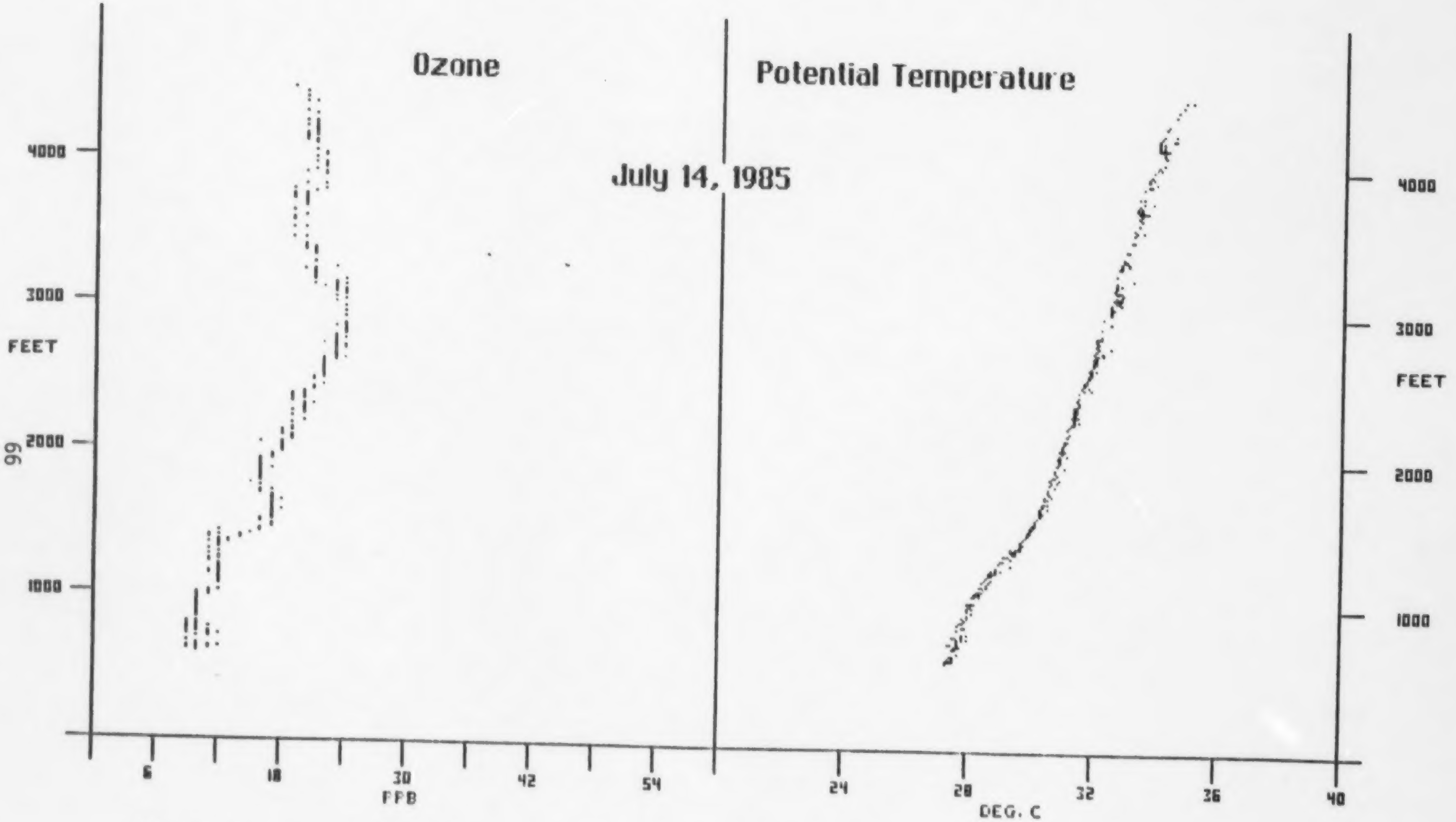


Figure A-20. Potential temperature and ozone changes with altitude on July 14, 1985

APPENDIX B

Aircraft Flight Maps and Pollutant Measurement Data Obtained from Tulsa, Oklahoma

TULSA AIR QUALITY DATA

This section provides a tabulation of airborne data collected in the Tulsa area during the period July 16-24, 1985. For each sampling day, there is a flight map with ozone concentrations marked along the route, a tabulation of air quality data, a listing of individual hydrocarbon concentrations and a graphical summary of ozone, NO_x and temperature changes with altitude.

NOTES on NMHC Tables

- * Means data not available
- - Means concentration less than 0.1 ppbC
- ( ) Ethylene values in parentheses were calculated by multiplying the propane concentration by 0.18. This was necessary in cases of obvious ethylene contamination due to the presence of a chemiluminescent ozone analyzer. The ethylene-propane ratio was derived from airborne samples that were free of contamination problems.

TNMHC is the sum of all gas chromatographic peaks

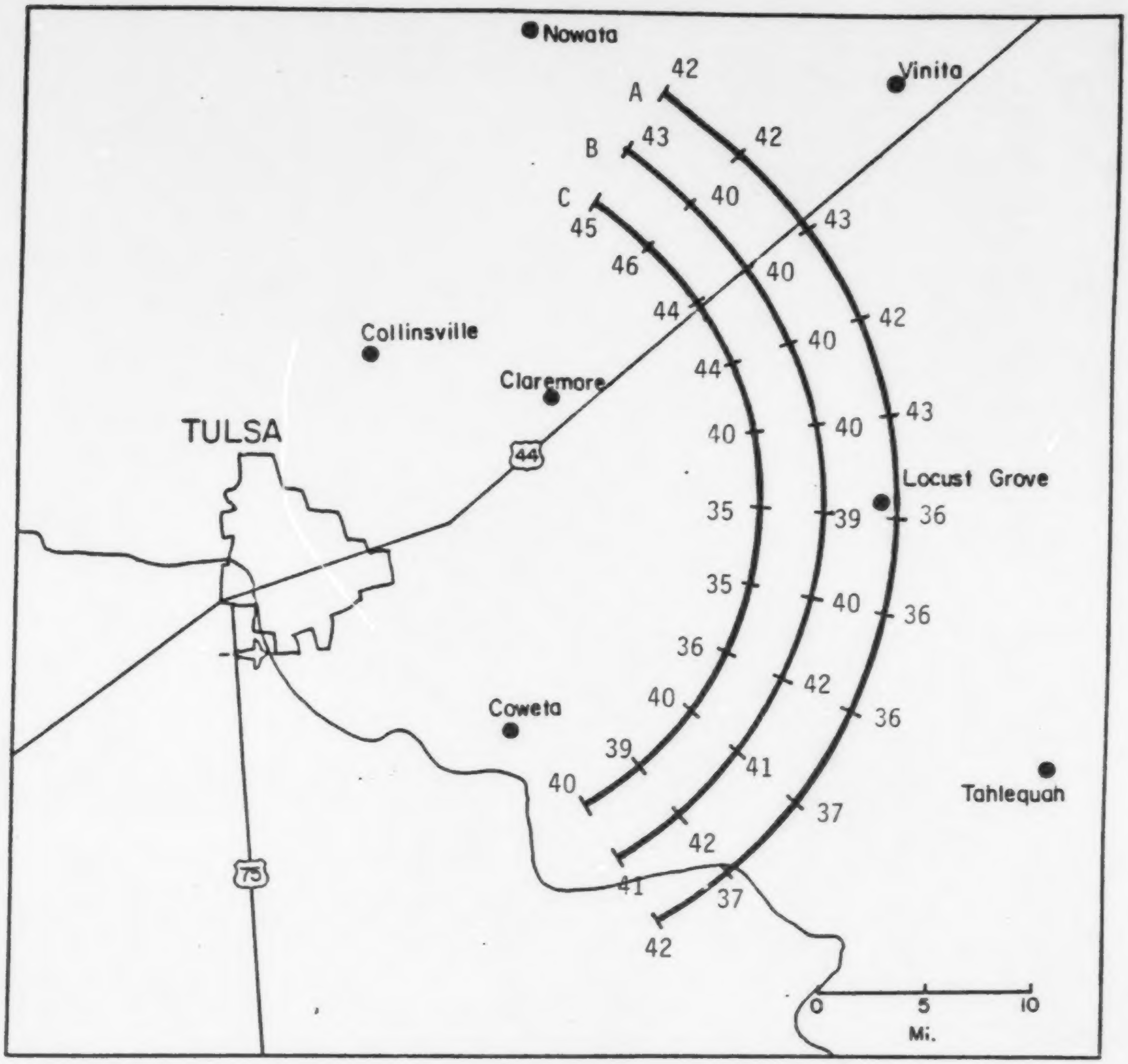

Nowata
Vinita
A
42
42
B
43
C
40
43
45
40
46
42
44
40
Collinsville
44
Claremore
40
40
43
TULSA
44
Locust Grove
35
39
36
35
40
36
36
42
40
Coweta
36
39
41
40
Tahlequah
37
42
41
37
42
75
0
5
10
Mi.

Figure B-1. July 16 flight path with ozone concentrations (ppb) marked along the route.

Time (CDT) and Altitude (AGL)

A: 0648 - 0718 at 2000'

B: 0723 - 0751 at 3000'

C: 0755 - 0822 at 2000'

Wind: 090° at 9 mph knots

July 16, 1985

Morning Mixing Level: Unknown

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/030	2000'	06:48:56	42	5	7	24.3	21.4	3.3	0.2
A/042		06:51:56	42	4	7	24.2			
A/054		06:54:57	43	4	6	23.9			
A/066		06:57:58	42	4	7	24.1			
A/078		07:00:58	43	5	7				
A/090		07:03:58	36	6	8	24.4			
A/102		07:06:59	36	5	7	24.9			
A/114		07:09:59	36	5	7	24.9			
A/126		07:12:59	37	5	7	25.1			
A/138		07:15:59	37	6	9	25.1			
A/150		07:18:51	42	5	9	25.6			
B/150	3000'	07:23:55	41	4	8	24.0	20.6	1.6	2.5
B/138		07:26:46	42	3	8	23.9			
B/126		07:29:26	41	3	7	23.9			
B/114		07:32:16	42	4	7	23.8			
B/102		07:34:56	40	3	5	23.9			
B/090		07:37:26	39	5	6	24.1			
B/078		07:40:22	40	6	7	24.3			
B/066		07:43:02	40	4	6	24.1			
B/054		07:45:42	40	4	7	23.8			
B/042		07:48:22	40	3	7				
B/030		07:50:42	43	6	5	23.9			
C/030	2000'	07:55:05	45	5	6	25.1	19.4	2.6	<0.1
C/042		07:57:56	46	4	9				
C/054		08:00:16	44	5	8	24.8			
C/066		08:02:56	44	5	9	24.7			
C/078		08:05:36	40	5	8	24.6			
C/090		08:08:16	35	5	8	24.8			
C/102		08:10:56	35	5	9	24.8			
C/114		08:13:26	36	6	9	24.9			
C/126		08:16:00	40	4	7	25.3			
C/138		08:18:40	39	3	6	25.3			
C/150		08:21:20	40	4	8	25.5			

* See flight map for Arc; Radial off Tulsa VOR.

Table B-1. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 16, 1985

Hydrocarbon	A/C Arc A 0658 - 0707 (CDT)	A/C Arc B 0737 - 0742 (CDT)	A/C Arc C 0804 - 0813 (CDT)
Ethane	4.5	6.4	3.9
Ethylene	(0.6)	(0.9)	(0.5)
Acetylene	0.5	0.5	0.2
Propane	3.6	5.2	2.9
Propene	-	-	-
i-Butane	0.8	1.0	0.6
n-Butane	1.9	2.3	1.5
i-Pentane	0.8	0.8	0.7
n-Pentane	0.5	0.7	0.6
Cyclopentane	1.6	0.2	2.4
Isoprene	2.2	-	4.0
2,3-Dimethylbutane	-	-	-
2-Methylpentane	0.3	0.2	0.2
3-Methylpentane	-	0.1	-
n-Hexane	0.3	0.2	-
Methylcyclopentane	0.1	0.1	-
Benzene	0.4	0.4	-
Cyclohexane	-	-	-
2-Methylhexane	0.5	0.4	0.1
3-Methylhexane	1.0	0.9	1.0
2,2,4-Trimethylpentane	-	-	-
Toluene	0.4	0.3	-
n-Octane	-	-	0.1
Ethylbenzene	0.1	-	0.2
p & *m*-Xylene	0.1	-	0.2
o-Xylene	1.2	-	0.1
Total Identified HC	21.4	20.6	19.4
TOTAL NMHC	25.5	24.2	23.8
% Paraffins	75	91	72
% Olefins	13	4	24
% Aromatics	10	3	3

No Data

Figure B-2. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on July 16, 1985.

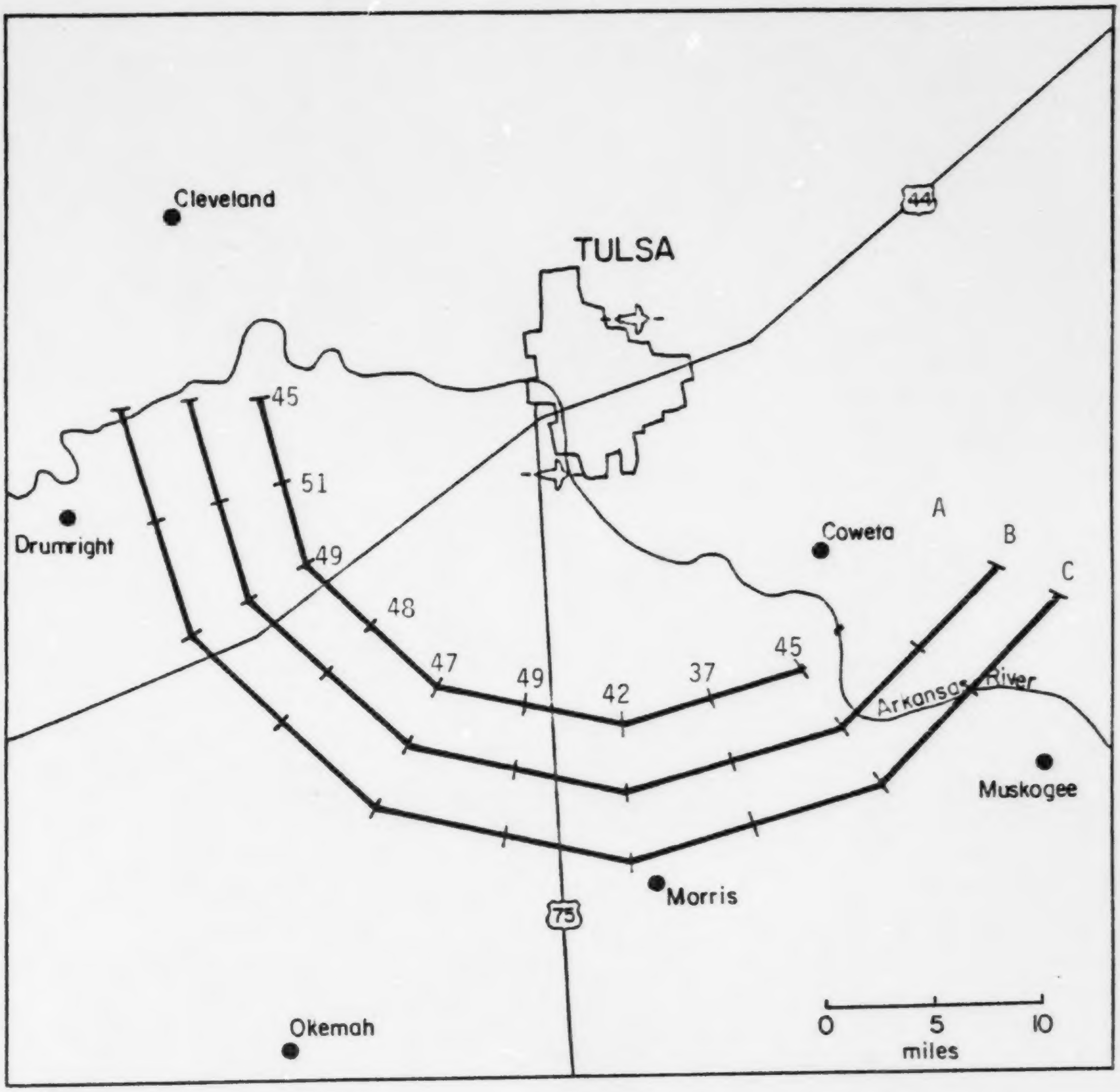

Cleveland
TULSA
44
Drumright
Coweta
A
B
C
45
51
49
48
47
49
42
37
45
Arkansas River
Muskogee
Morris
75
Okemah
0
5
10
miles

Figure 3-3. July 17 flight path with ozone concentrations (ppb) marked along the route.

Time (CDT) and Altitude (AGL)

A: 0647 - 0714 at 2000'

B:
Aborted due to weather
C:

Wind: 150° at 14 knots

July 17, 1985

Morning Mixing Level: **Unknown**

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/252		06:47:31	45	3	8	23.2			
A		06:50:52	51	6	7	23.1			
A		06:54:23	49	4	7	22.9			
A		06:57:24	48	5	8	22.8			
A	2000'	07:00:25	47	4	7	22.6	21.2	2.6	<0.1
A		07:04:05	49	5	7	22.4			
A		07:07:55	42	4	6	21.4			
A		07:10:47	37	5	7	19.6			
A/159		07:13:17	45	4	5	19.5			

* See flight map for Arc; Radial off Tulsa VOR.

Table B-2. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 17, 1985

Hydrocarbon	A/C Arc A 0657 - 0706 (CDT)	A/C Arc B - (CDT)	A/C Arc C - (CDT)
Ethane	5.0		
Ethylene	0.7		
Acetylene	0.7		
Propane	3.7		
Propene	0.3		
i-Butane	1.1		
n-Butane	1.6		
i-Pentane	0.9		
n-Pentane	0.7		
Cyclopentane	1.0		
Isoprene	0.2		
2,3-Dimethylbutane	-		
2-Methylpentane	0.3		
3-Methylpentane	0.1		
n-Hexane	0.3		
Methylcyclopentane	-		
Benzene	0.8		
Cyclohexane	-		
2-Methylhexane	0.6		
3-Methylhexane	1.4		
2,2,4-Trimethylpentane	-		
Toluene	0.6		
n-Octane	-		
Ethylbenzene	0.5		
p & *m*-Xylene	0.3		
o-Xylene	0.4		
Total Identified HC	21.2		
TOTAL NMHC	24.3		
% Paraffins	80		
% Olefins	6		
% Aromatics	11		

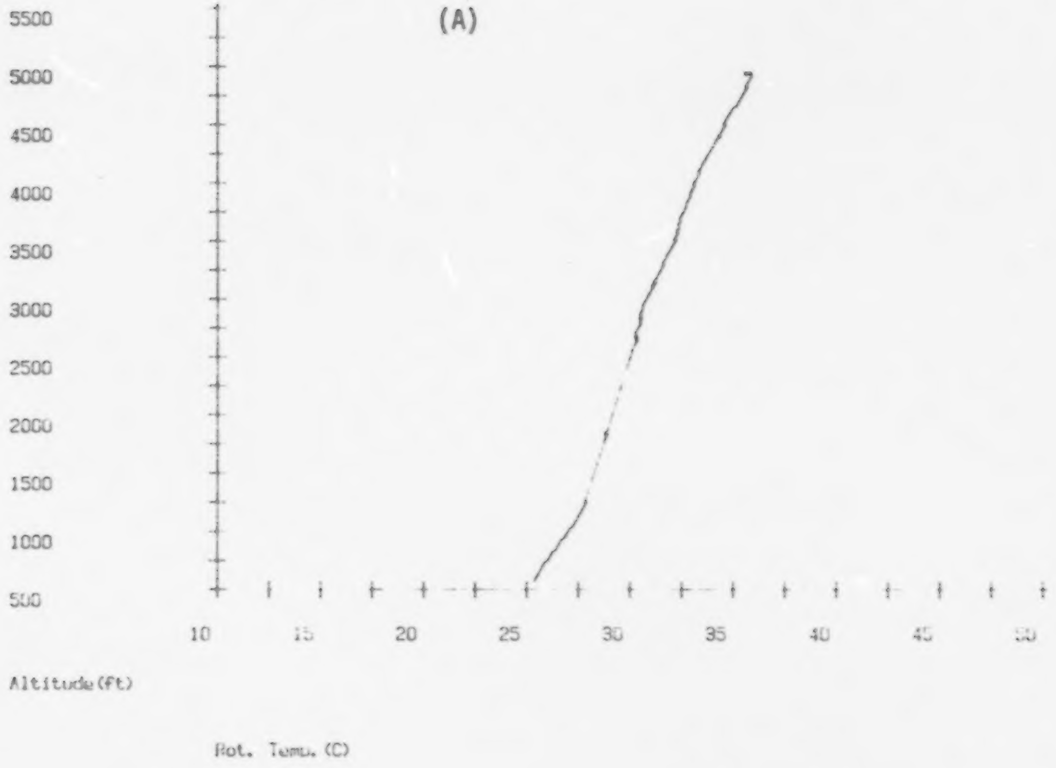
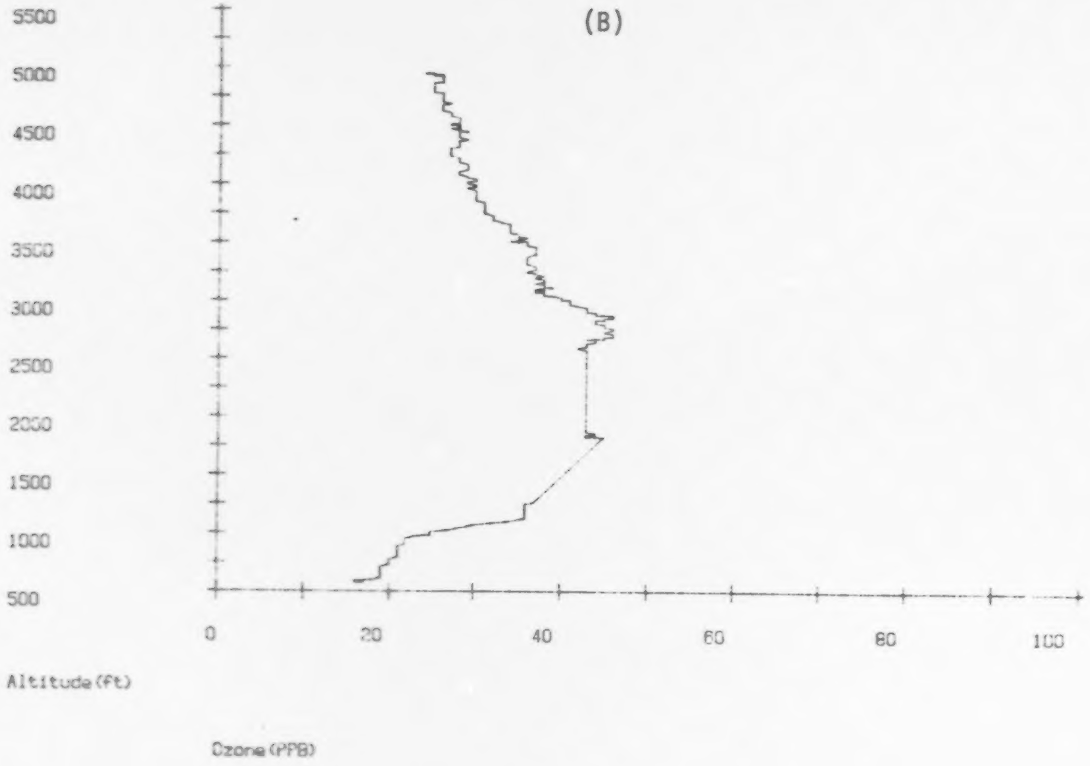
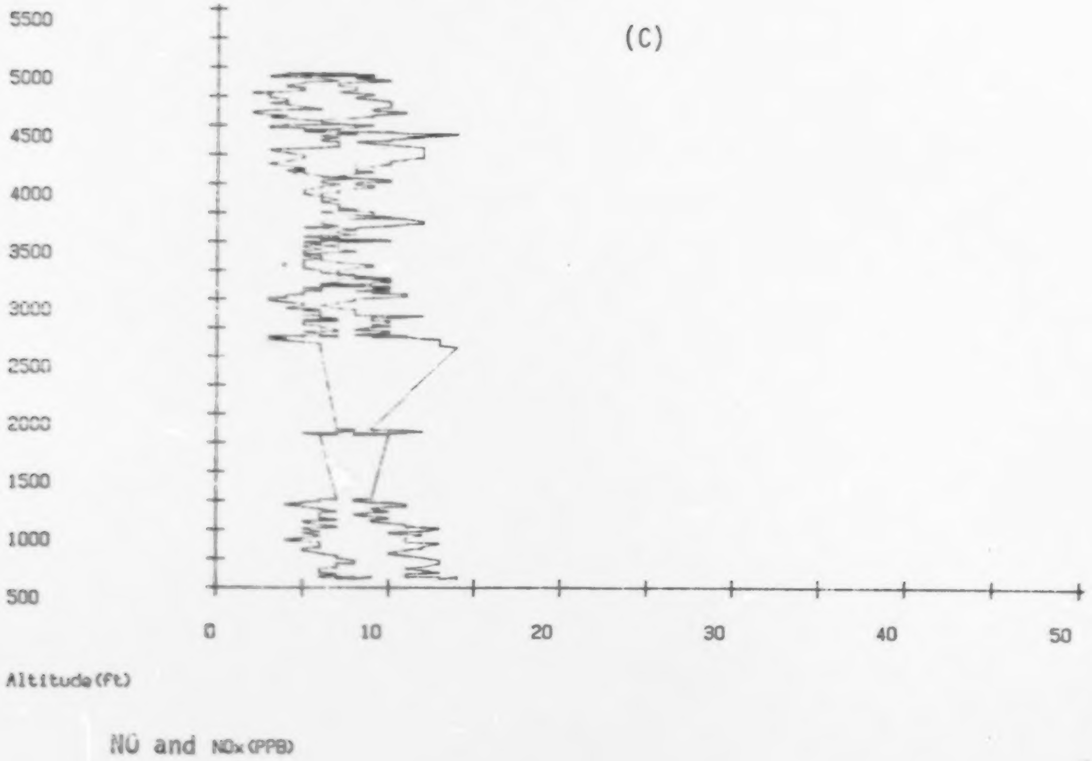
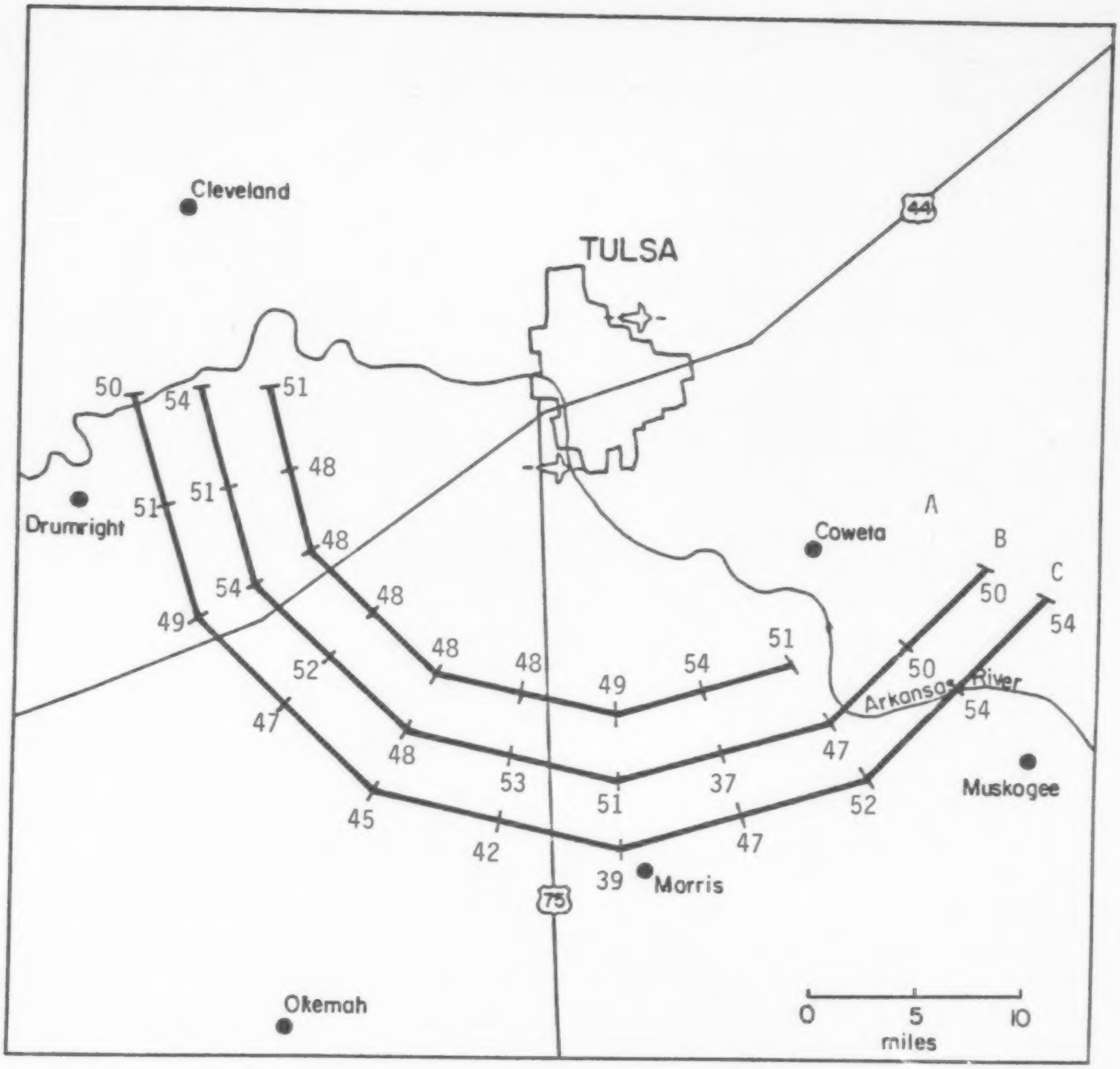


Figure B-4. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on July 17, 1985.

(Figure B -4. cont'd.)






Cleveland
TULSA
44
Drumright
Coweta
A
B
C
50
54
51
51
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48
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48
48
49
54
51
52
47
48
53
51
37
47
50
50
45
42
39
47
52
54
54
Arkansas River
Muskogee
Morris
75
Okemah
0
5
10
miles

Figure 3-5. July 18 flight path with ozone concentrations (ppb) marked along the route.

Time (CDT) and Altitude (AGL)

A: 0632 - 0655 at 2000'

B: 0702 - 0734 at 3000'

C: 0737 - 0814 at 2000'

Wind: 170° at 15 knots

July 18, 1985

Morning Mixing Level: 1100 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/252	2000'	06:32:38	48	7	8	24.5	31.7	1.5	<0.1
A		06:36:18	48	5	7	24.4			
A		06:39:29	48	7	10	24.6			
A		06:42:40	48	4	7	24.5			
A		06:45:49	48	6	7	24.5			
A		06:48:49	49	5	7	24.5			
A		06:50:59	54	5	7	24.3			
A/159		06:54:30	51	3	9	24.4			
B/125	3000'	07:02:04	50	4	8	23.0	35.8	4.1	<0.1
B		07:05:25	50	4	9	22.7			
B		07:08:45	47	5	10	22.6			
B		07:12:35	37	5	11	22.4			
B		07:16:15	51	3	11	22.6			
B		07:19:46	53	5	6	22.6			
B		07:23:06	48	4	9	22.4			
B		07:25:46	52	4	8	22.6			
B		07:28:26	54	5	7	22.9			
B		07:31:06	51	6	7	22.9			
B/250		07:33:56	54	6	7	23.5			
C/250	2000'	07:37:35	50	5	9	24.8	43.9	6.6	0.9
C		07:41:25	51	5	8	25.0			
C		07:45:15	49	6	10	25.0			
C		07:49:05	47	4	9	25.0			
C		07:52:45	45	6	9	25.0			
C		07:56:25	42	4	10	24.9			
C		08:00:04	39	4	15	24.5			
C		08:03:55	47	5	9	24.6			
C		08:07:55	52	5	9	24.8			
C		08:10:35	54	4	6	24.5			
C/123		08:13:05	54	5	6	24.5			

* See flight map for Arc; Radial off Tulsa VOR.

Table B-3. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 18, 1985

Hydrocarbon	A/C Arc A 0636 - 0647 (CDT)	A/C Arc B 0715 - 0725 (CDT)	A/C Arc C 0751 - 0801 (CDT)
Ethane	7.5	10.3	7.7
Ethylene	(1.1)	(1.3)	(1.1)
Acetylene	0.5	0.5	0.7
Propane	6.2	7.3	6.0
Propene	0.3	0.3	0.7
i-Butane	2.2	2.4	2.6
n-Butane	3.7	3.5	5.1
i-Pentane	2.0	1.9	2.8
n-Pentane	1.5	1.7	1.7
Cyclopentane	-	1.1	1.4
Isoprene	1.4	0.2	0.5
2,3-Dimethylbutane	0.2	0.1	0.1
2-Methylpentane	0.7	0.6	0.9
3-Methylpentane	0.3	0.3	1.7
n-Hexane	0.8	0.7	0.8
Methylcyclopentane	0.2	0.2	0.3
Benzene	0.6	0.9	1.5
Cyclohexane	-	-	0.1
2-Methylhexane	0.4	0.5	1.0
3-Methylhexane	0.3	0.4	2.2
2,2,4-Trimethylpentane	0.2	0.2	0.3
Toluene	0.6	0.8	2.1
n-Octane	0.2	0.2	-
Ethylbenzene	0.1	0.1	0.3
p & *m*-Xylene	0.4	0.2	0.4
o-Xylene	0.3	0.1	1.9
Total Identified HC	31.7	35.8	43.9
TOTAL NMHC	32.6	37.4	53.0
% Paraffins	83	85	78
% Olefins	9	5	5
% Aromatics	6	6	14

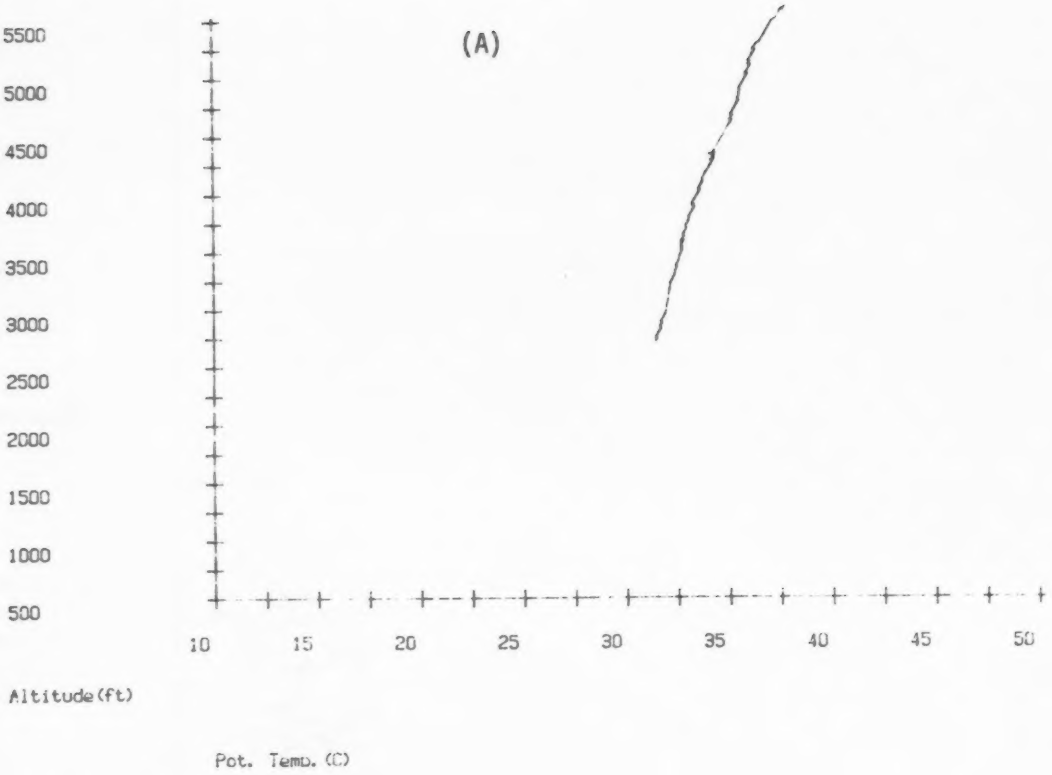
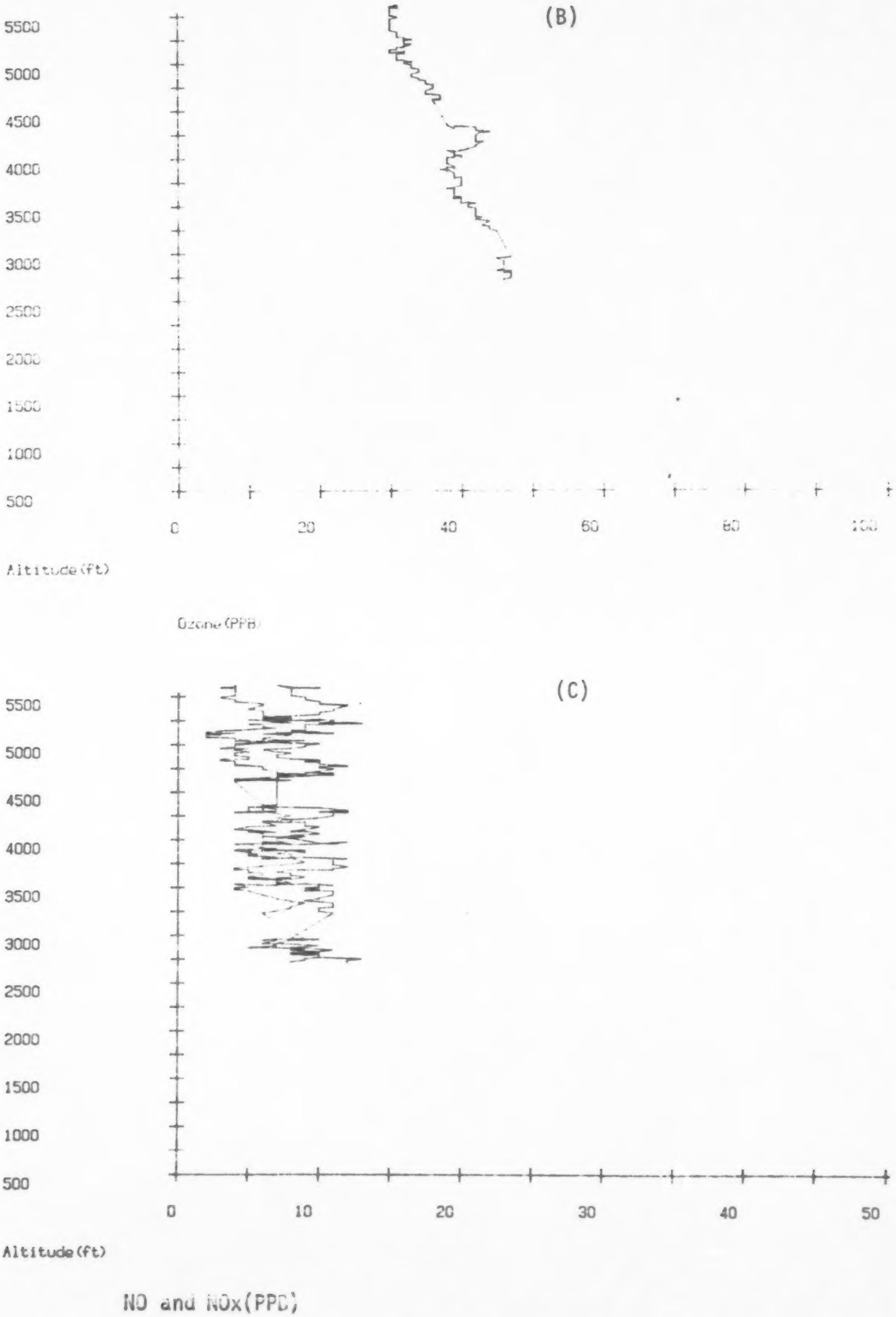
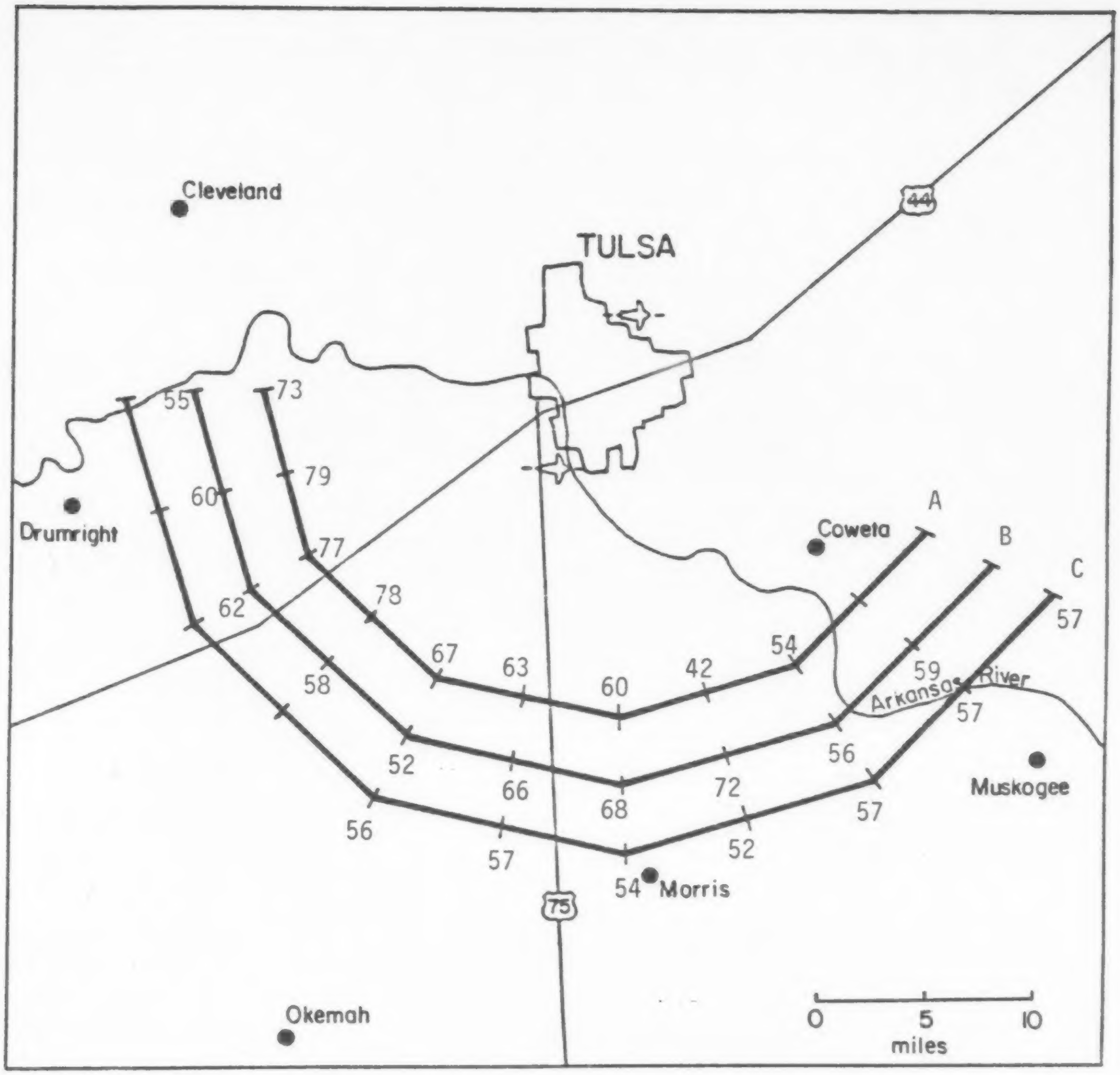


Figure B-6. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on July 18, 1985.

(Figure B-6. cont'd.)




Cleveland
TULSA
44
Drumright
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73
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79
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78
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67
63
60
42
54
Coweta
A
B
C
57
59
Arkansas River
57
56
52
66
68
72
56
57
57
52
54
Morris
Muskogee
75
Okemah
0
5
10
miles

Figure B-7. July 19 flight path with ozone concentrations (ppb) marked along the route.

Time (CDT) and Altitude (AGL)

A: 0635 - 0658 at 2000'

B: 0706 - 0737 at 3000'

C: 0739 - 0812 at 3000'

Wind: 190° at 15 knots

July 19, 1985

Morning Mixing Level: Unknown

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/252	2000'	06:38:07	79	12	12		35.5	3.8	1.0
A		06:41:27	77	11	12				
A		06:43:57	78	11	12				
A		06:46:17	67	10	10				
A		06:49:27	63	10	13				
A		06:52:42	60	8	13				
A		06:55:13	42	8	19				
A/159		06:57:53	54	8	14				
B/121	3000'	07:12:31	56	10	12		73.6	8.3	1.1
B		07:16:43	72	8	13				
B		07:20:24	68	6	9				
B		07:23:14	66	6	8				
B		07:26:19	52	8	9				
B		07:29:19	58	7	8				
B		07:32:28	62	9	10				
B		07:34:38	60	6	8				
B/250		07:36:48	55	7	13				
C/205	3000'	07:51:38	56	7	11		65.5	8.4	2.0
C		07:54:38	57	7	11				
C		07:57:38	54	3	9				
C		08:01:18	52	8	9				
C		08:04:58	57	6	8				
C		08:08:08	57	7	11				
C/123		08:11:08	57	6	9				

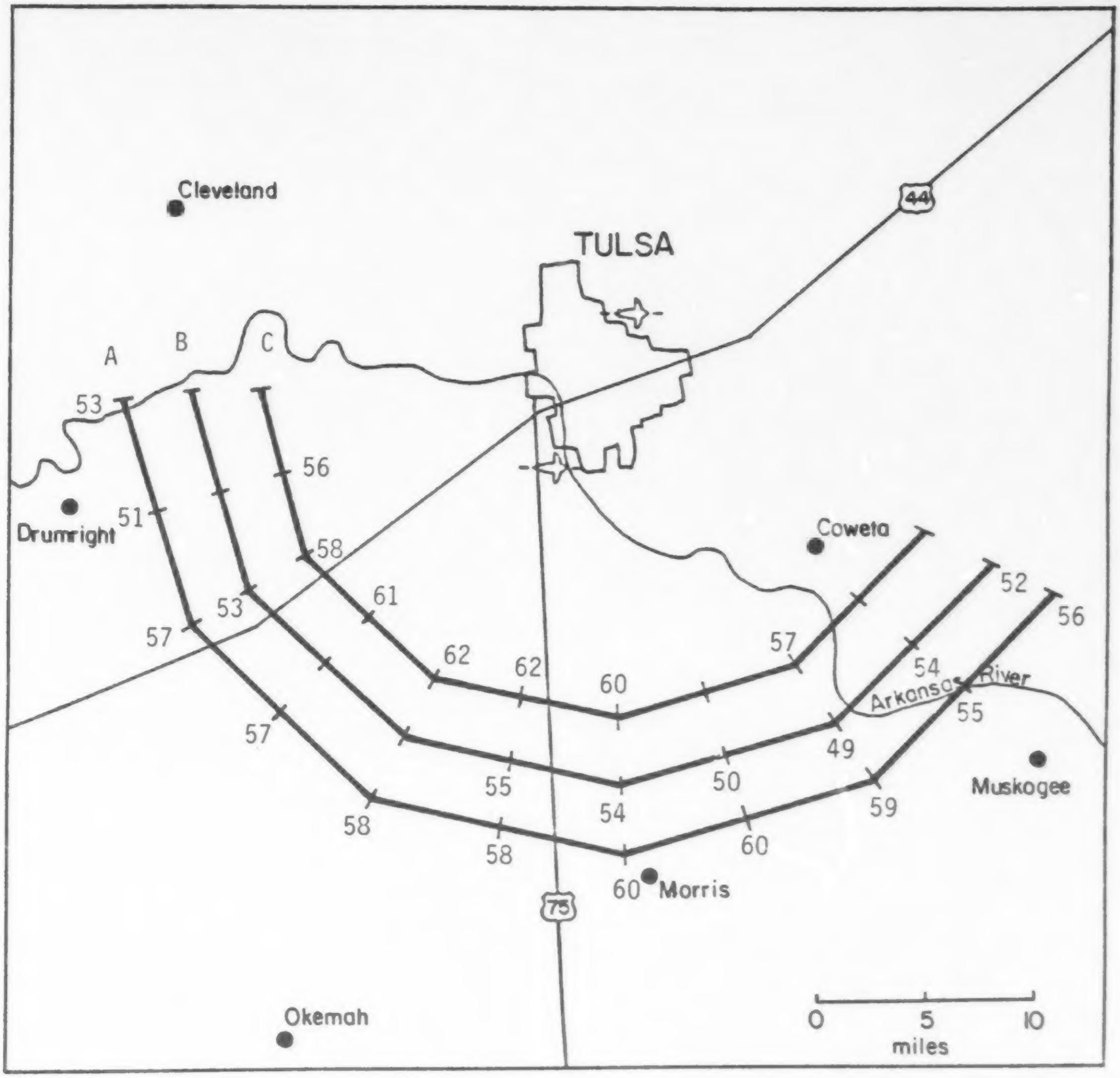
* See flight map for Arc; Radial off Tulsa VOR.

Table B-4. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 19, 1985

Hydrocarbon	A/C Arc A 0642 - 0655 (CDT)	A/C Arc B 0717 - 0726 (CDT)	A/C Arc C 0754 - 0803 (CDT)
Ethane	8.5	13.5	11.5
Ethylene	(1.1)	(2.2)	(1.7)
Acetylene	0.6	1.1	1.1
Propane	6.1	12.3	9.7
Propene	0.4	0.9	0.9
i-Butane	2.2	6.7	6.4
n-Butane	3.9	7.8	7.7
i-Pentane	2.2	5.3	4.1
n-Pentane	1.7	5.4	3.0
Cyclopentane	0.8	1.0	2.8
Isoprene	-	1.4	2.2
2,3-Dimethylbutane	0.2	0.4	0.4
2-Methylpentane	0.7	2.0	1.6
3-Methylpentane	0.4	1.1	0.7
n-Hexane	0.7	1.9	1.4
Methylcyclopentane	0.3	1.0	0.5
Benzene	1.2	2.5	3.2
Cyclohexane	-	0.2	0.2
2-Methylhexane	0.2	0.9	0.8
3-Methylhexane	0.9	1.0	0.3
2,2,4-Trimethylpentane	0.2	-	0.6
Toluene	1.4	2.7	2.2
n-Octane	0.1	0.3	0.9
Ethylbenzene	0.3	0.2	0.4
p & *m*-Xylene	0.4	0.9	0.6
o-Xylene	1.0	0.9	0.6
Total Identified HC	35.5	73.6	65.5
TOTAL NMHC	44.5	76.3	69.5
% Paraffins	82	82	80
% Olefins	4	6	7
% Aromatics	12	10	11

No Data

Figure B-8. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on July 19, 1985.


Cleveland
TULSA
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A
B
C
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Drumright
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62
60
57
Coweta
52
56
54
Arkansas River
55
57
55
54
50
49
58
58
60
59
Muskogee
60
Morris
75
Okemah
0
5
10
miles

Figure B-9. July 20 flight path with ozone concentrations (ppb) marked along the route.

Time (CDT) and Altitude (AGL)

A: 0627 - 0658 at 2000'

B: 0701 - 0731 at 3000'

C: 0734 - 0804 at 3000'

Wind: light and variable (∿190°)

July 20, 1985

Morning Mixing Level: 900 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/250	2000'	06:27:47	53	6	10	27.8	15.3	2.6	0.1
A		06:29:38	51	7	11	27.5			
A		06:32:29	57	6	11	27.3			
A		06:36:09	57	6	9	27.0			
A		06:40:55	58	7	10	27.1			
A		06:42:15	58	6	10	27.1			
A		06:44:45	60	6	10	26.8			
A		06:48:25	60	6	9	26.9			
A		06:51:55	59	8	9	26.9			
A		06:54:55	55	7	10	27.3			
A/129		06:57:55	56	8	7	27.5			
B/125	3000'	07:01:18	52	5	6	25.0	79.6	2.6	0.8
B		07:03:49	54	7	8	24.5			
B		07:06:29	49	5	7	24.7			
B		07:09:39	50	6	7	24.5			
B/182		07:13:00	54	8	10	24.5			
C/184	3000'	07:37:42	56	5	9	27.2	13.3	3.8	1.7
C		07:40:42	58	7	10	26.9			
C		07:43:33	61	6	11	26.8			
C		07:46:23	62	6	10	26.7			
C		07:48:33	62	6	10	26.7			
C/244		07:51:34	60	6	8	26.8			

* See flight map for Arc; Radial off Tulsa VOR.

Table B-5. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 20, 1985

Hydrocarbon	A/C Arc A 0636 - 0646 (CDT)	A/C Arc B 0712 - 0721 (CDT)	A/C Arc C 0745 - 0754 (CDT)
Ethane	5.9	17.1	4.1
Ethylene	(0.5)	(2.4)	(0.5)
Acetylene	0.9	1.2	0.6
Propane	2.7	13.1	2.7
Propene	0.1	2.1	-
i-Butane	0.4	15.4	0.9
n-Butane	1.1	12.4	1.3
i-Pentane	0.5	3.7	0.7
n-Pentane	0.6	2.8	0.4
Cyclopentane	0.3	-	-
Isoprene	0.2	1.4	-
2,3-Dimethylbutane	-	0.3	-
2-Methylpentane	0.2	1.1	0.2
3-Methylpentane	-	0.6	0.2
n-Hexane	0.2	1.0	0.2
Methylcyclopentane	-	0.6	-
Benzene	0.4	1.1	0.6
Cyclohexane	-	0.2	-
2-Methylhexane	0.1	0.6	-
3-Methylhexane	0.2	0.1	-
2,2,4-Trimethylpentane	-	0.5	-
Toluene	0.2	1.7	0.4
n-Octane	-	0.2	-
Ethylbenzene	0.4	*	0.2
p & *m*-Xylene	0.2	*	0.1
o-Xylene	0.2	*	0.2
Total Identified HC	15.3	79.6	13.3
TOTAL NMHC	15.3	84.3	16.6
% Paraffins	81	*	80
% Olefins	5	*	4
% Aromatics	8	*	11

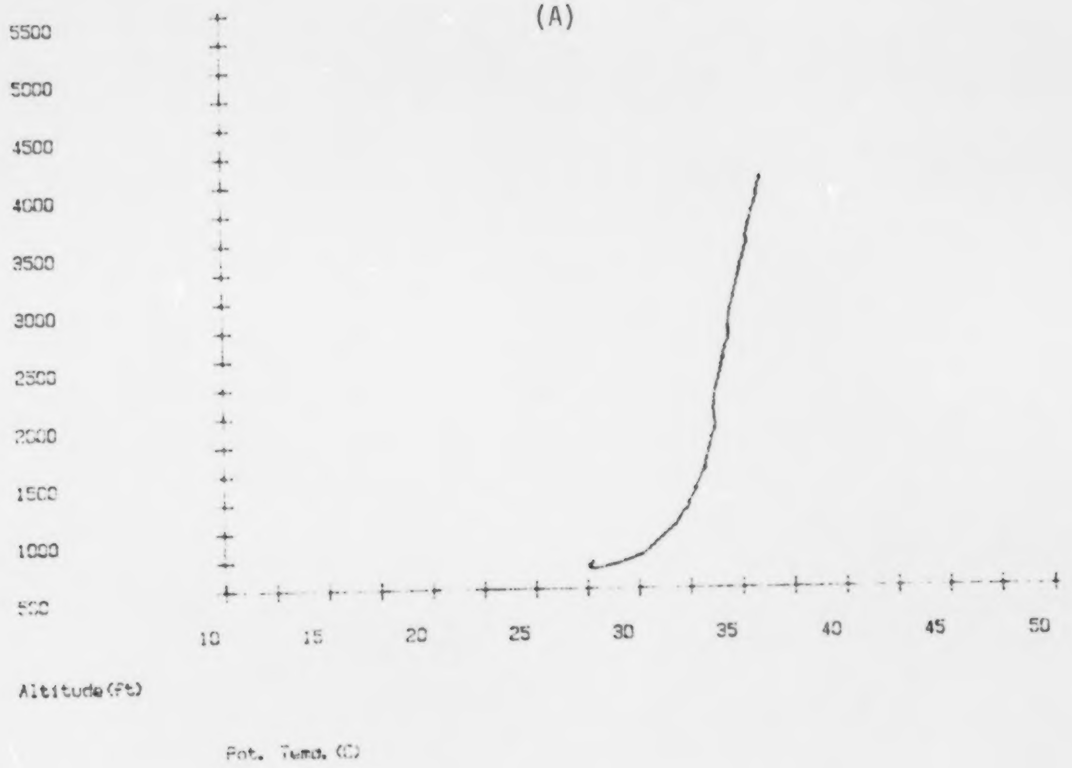
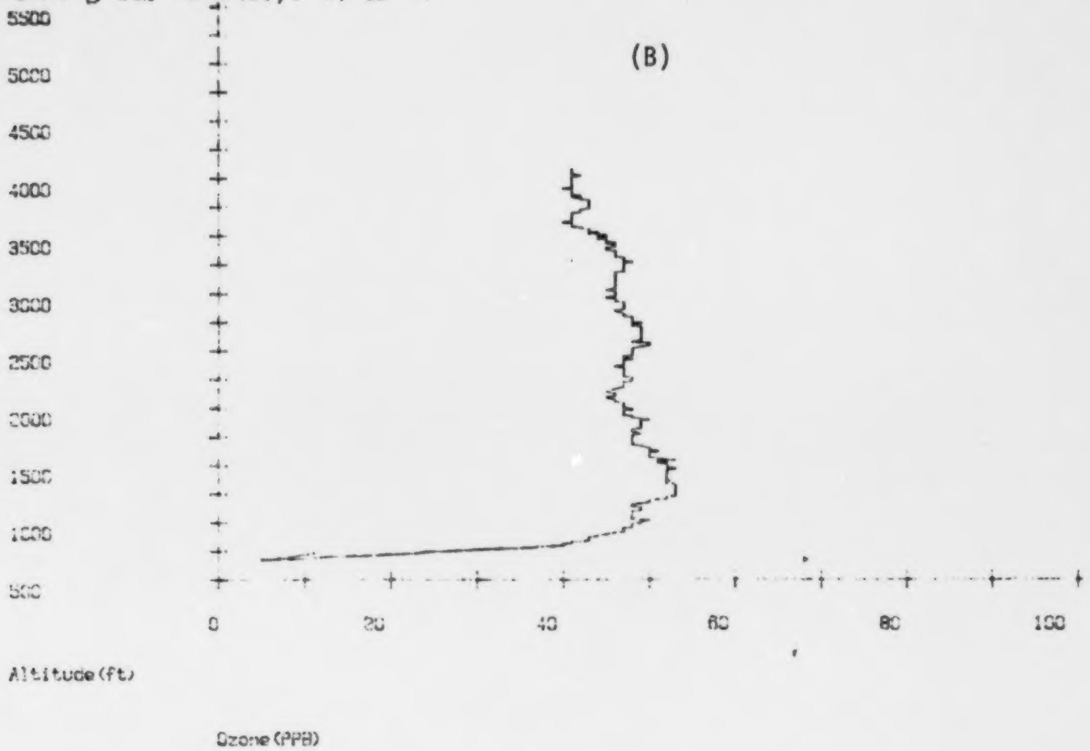
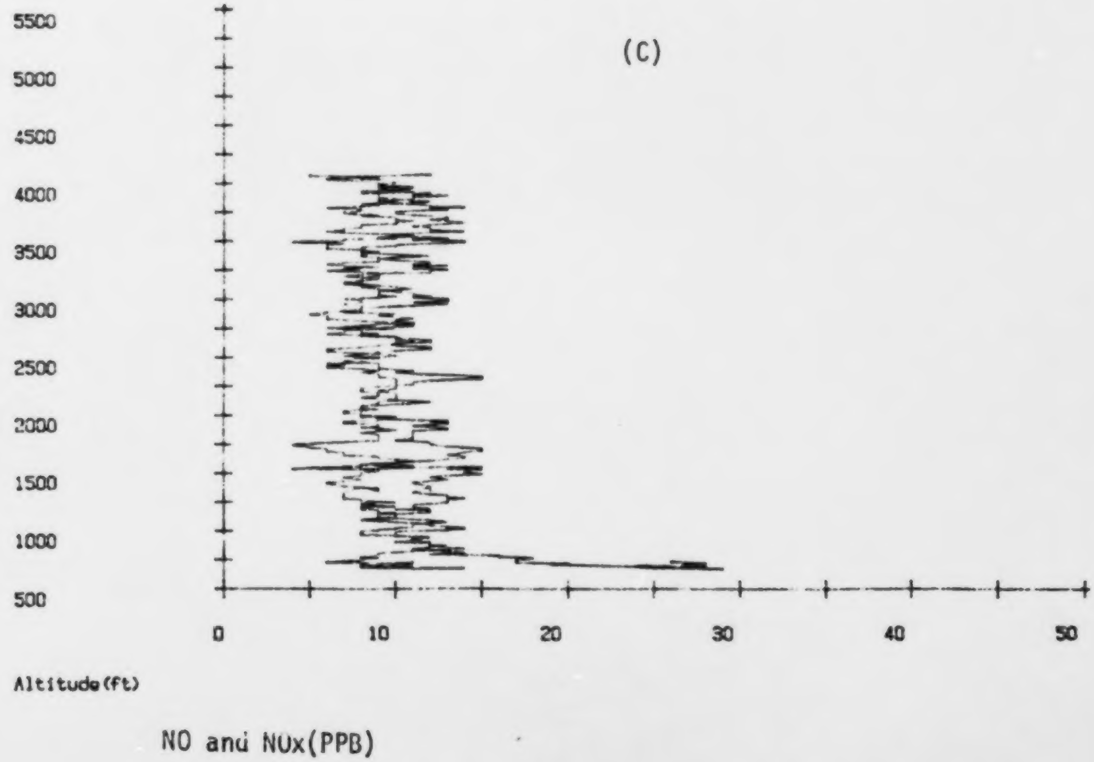


Figure B-10. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on July 20, 1985.

(Figure B-10. cont'd.)





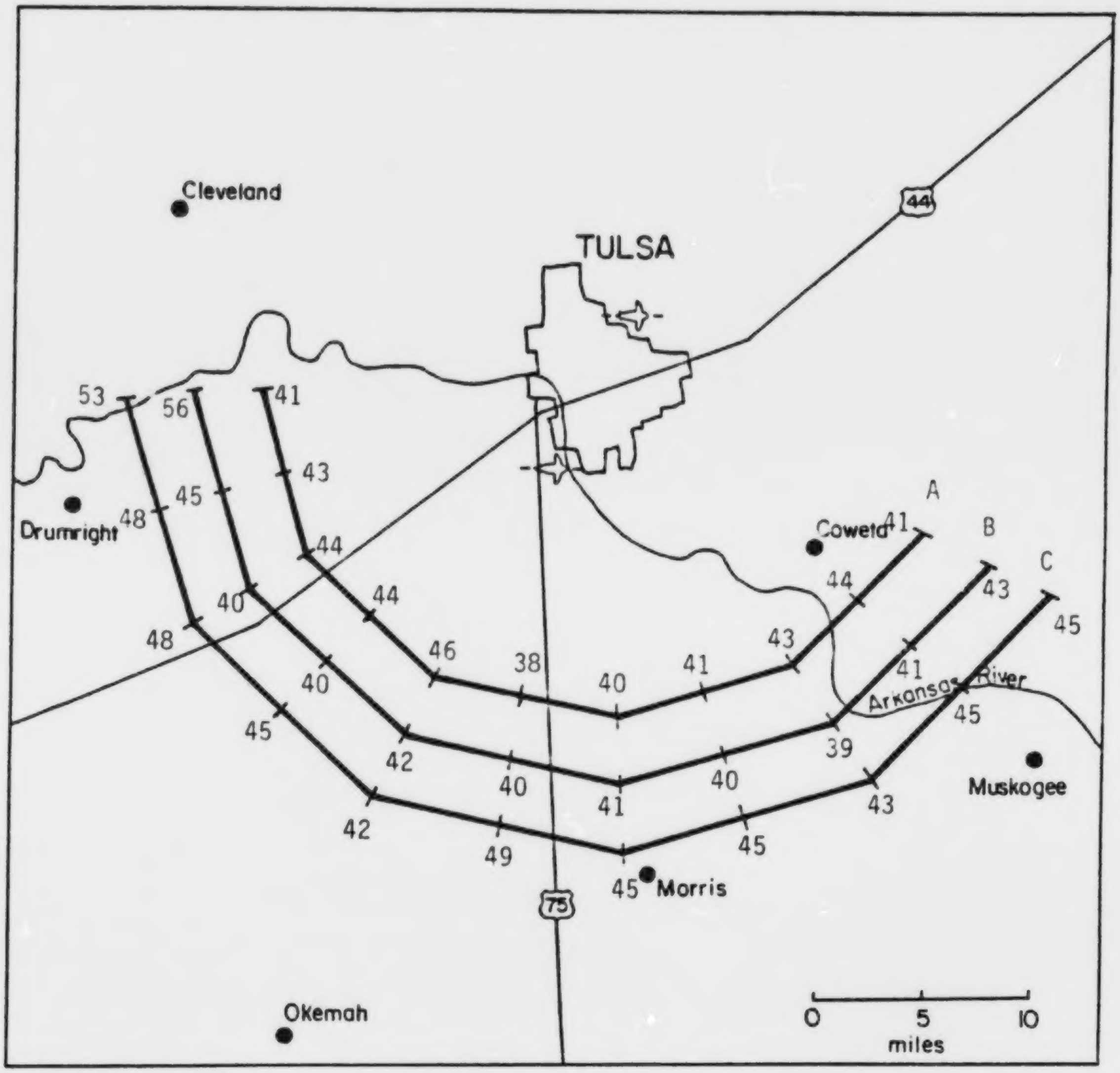

Cleveland
TULSA
44
Drumright
Coweta
A
B
C
Arkansas River
Muskogee
Morris
75
Okemah
0
5
10
miles
41
43
44
44
46
38
40
41
43
44
41
56
45
40
40
42
40
41
40
39
41
43
53
48
48
45
42
49
45
45
43
45
45

Figure B-11. July 21 flight path with ozone concentrations (ppb) marked along the route.

Time (CDT) and Altitude (AGL)

A: 0641 - 0711 at 2000'

B: 0714 - 0745 at 3000'

C: 0747 - 0818 at 2000'

Wind: 210° at 8 knots

July 21, 1985

Morning Mixing Level: 800 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/252	2000'	06:41:10	41	6	12	25.3	31.7	2.7	0.4
A		06:44:02	43	4	8	24.8			
A		06:46:51	44	7	7	24.2			
A		06:49:52	44	6	9	24.3			
A		06:52:23	46	5	9	24.3			
A		06:55:14	38	5	8	24.4			
A		06:58:03	40	6	8	24.3			
A		07:01:14	41	4	7	24.2			
A		07:04:34	43	4	8	24.3			
A		07:07:23	44	5	9	24.7			
A/129		07:10:35	41	5	6	24.2			
B/125	3000'	07:14:17	43	5	6	22.6	30.7	0.9	1.8
B		07:17:19	41	7	7	20.9			
B		07:20:18	39	5	9	20.8			
B		07:23:48	40	5	8	20.8			
B		07:27:19	41	5	7	21.9			
B		07:30:39	40	5	5	22.3			
B		07:34:09	42	5	7	22.3			
B		07:36:59	40	5	8	22.2			
B		07:39:49	40	5	8	22.5			
B		07:42:09	45	3	8	22.6			
B/250		07:44:49	56	3	6	22.4			
C/250	2000'	07:47:06	53	6	9	24.9	22.2	1.8	<0.1
C		07:48:56	48	5	9	24.8			
C		07:52:06	48	6	7	24.2			
C		07:55:46	45	4	8	24.1			
C		07:59:36	42	4	9	24.7			
C		08:02:46	49	3	10	24.3			
C		08:05:49	45	4	8	24.2			
C		08:09:09	45	3	9	24.2			
C		08:12:19	43	3	8	24.3			
C		08:15:00	45	4	7	24.7			
C/123		08:17:41	45	4	8	24.7			

* See flight map for Arc; Radial off Tulsa VOR.

Table B-6. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 21, 1985

Hydrocarbon	A/C Arc A 0651 - 0700 (CDT)	A/C Arc B 0726 - 0735 (CDT)	A/C Arc C 0757 - 0806 (CDT)
Ethane	7.1	8.4	6.7
Ethylene	(0.7)	(1.0)	(0.8)
Acetylene	0.3	0.6	0.5
Propane	4.1	5.4	4.2
Propene	-	0.2	-
i-Butane	1.6	2.5	1.3
n-Butane	*	3.0	2.5
i-Pentane	1.9	1.9	1.2
n-Pentane	2.0	1.3	0.8
Cyclopentane	-	0.9	0.3
Isoprene	0.2	0.9	0.1
2,3-Dimethylbutane	0.2	0.2	0.1
2-Methylpentane	0.6	0.4	0.4
3-Methylpentane	-	0.6	0.2
n-Hexane	0.8	0.5	0.4
Methylcyclopentane	0.4	0.2	0.1
Benzene	1.6	0.8	0.6
Cyclohexane	0.3	0.1	-
2-Methylhexane	0.3	0.2	0.4
3-Methylhexane	1.5	0.3	0.3
2,2,4-Trimethylpentane	0.2	-	0.1
Toluene	3.2	0.6	0.4
n-Octane	-	0.1	0.1
Ethylbenzene	0.6	0.1	0.2
p & *m*-Xylene	2.7	0.2	0.3
o-Xylene	1.4	0.3	0.2
Total Identified HC	31.7	30.7	22.2
TOTAL NMHC	139	33.0	22.9
% Paraffins	66	84	86
% Olefins	4	7	4
% Aromatics	30	7	8

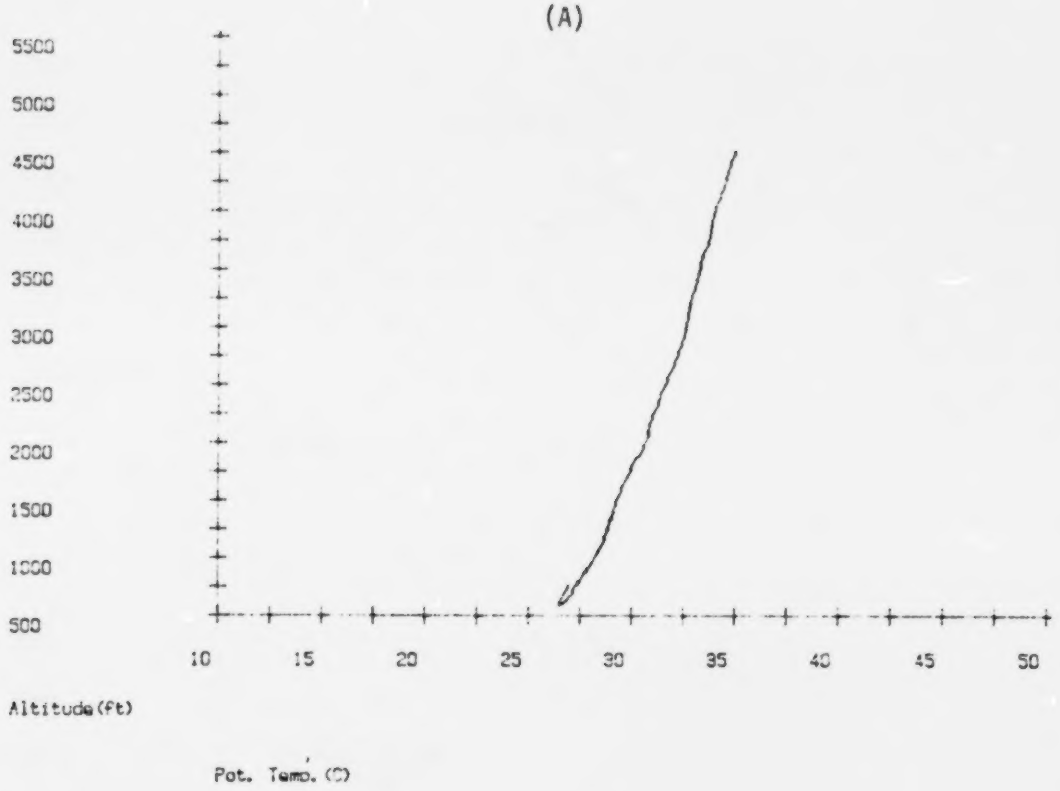
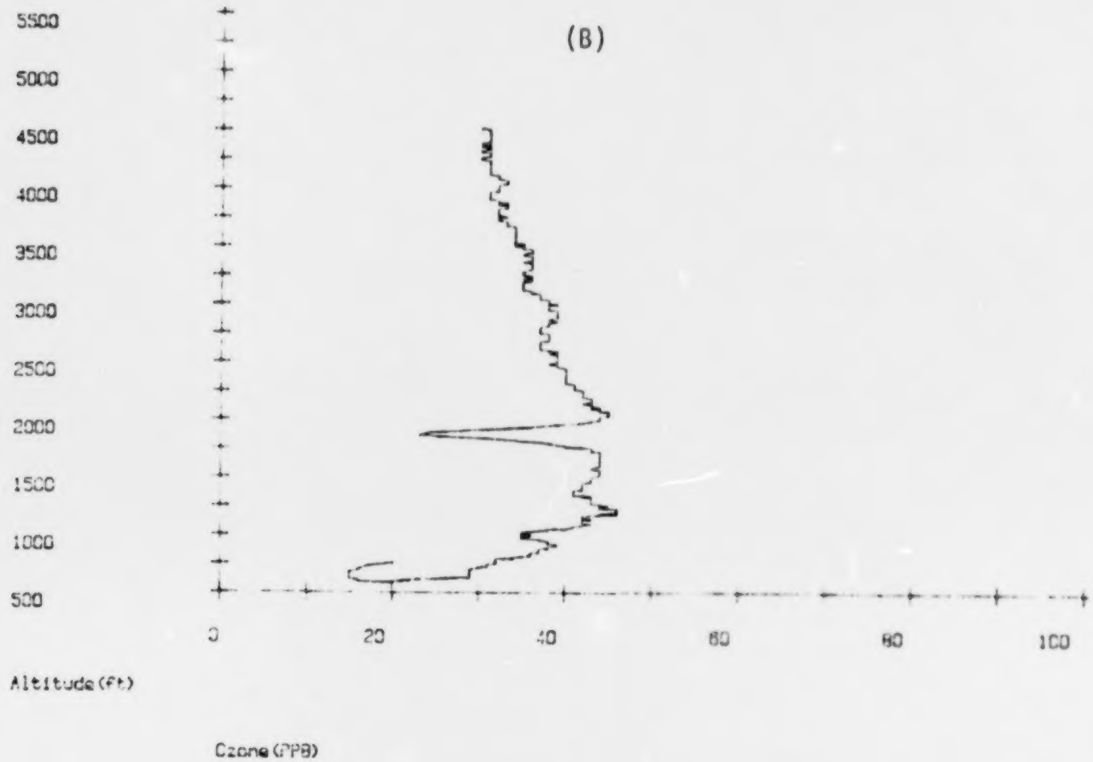
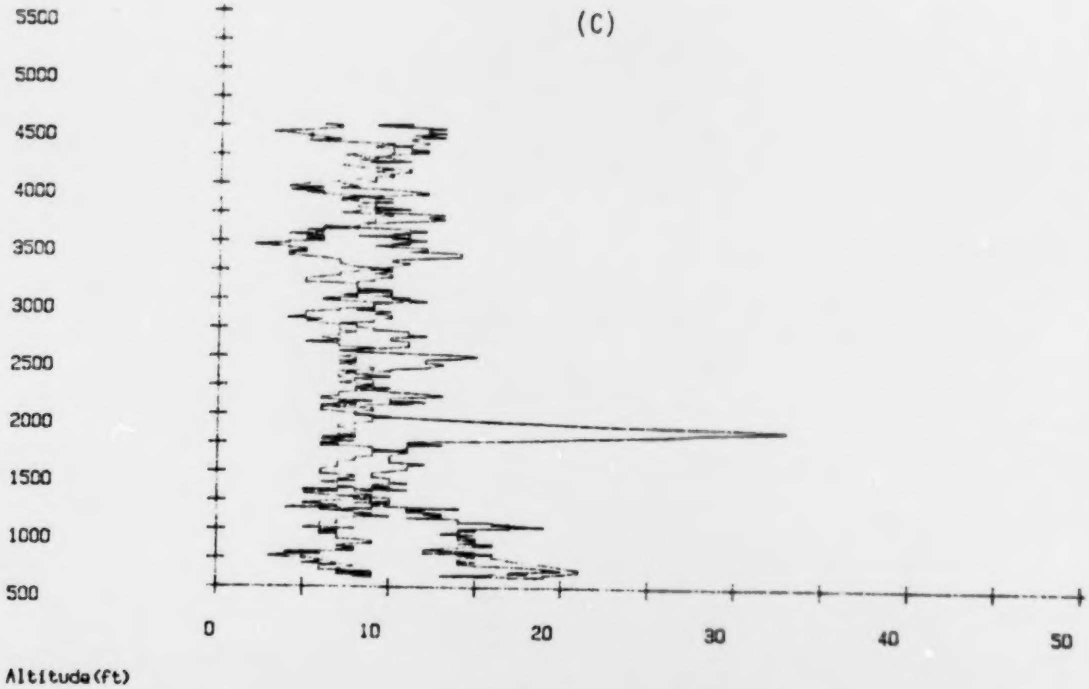


Figure B-12. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on July 21, 1985.

(Figure R-12. cont'd.)





NO and NOx(PPB)

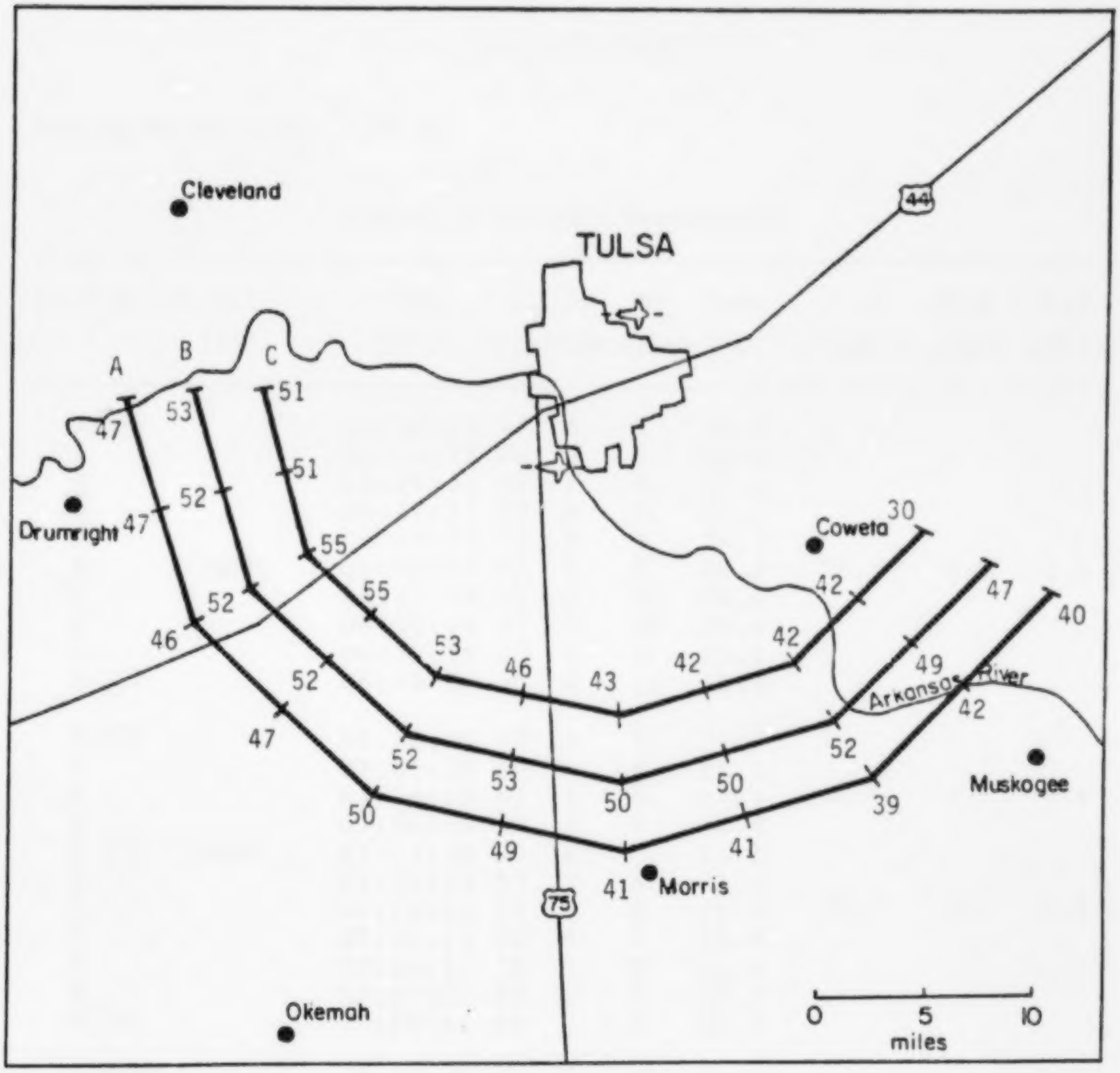

Cleveland
TULSA
44
A
B
C
47
53
51
51
47
52
Drumright
55
52
55
46
52
53
46
43
42
42
52
47
52
53
50
50
52
50
49
41
41
39
Coweta
30
42
47
49
40
42
Arkansas River
Muskogee
Morris
75
Okemah
0
5
10
miles

Figure B-13. July 22 flight path with ozone concentrations (ppb) marked along the route.

Time (CDT) and Altitude (AGL)

A: 0628 - 0657 at 2000'

B: 0700 - 0730 at 3000'

C: 0735 - 0801 at 2000'

Wind: light and variable

July 22, 1985

Morning Mixing Level: 800 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/250	2000'	06:28:26	47	5	9	24.2			
A		06:31:25	46	3	9	24.4			
A		06:34:35	47	6	8	24.4			
A		06:37:57	50	4	7	24.5			
A		06:40:57	49	5	9	24.7			
A		06:44:07	41	4	8	24.2	24.5	0.5	0.8
A		06:47:28	41	5	11	24.1			
A		06:50:49	39	7	10	23.6			
A		06:53:28	42	4	8	24.1			
A/123		06:56:28	40	6	11	23.8			
B/125	3000'	07:00:57	47	4	9	21.7			
B		07:03:28	49	4	8	22.1			
B		07:06:18	52	3	8	22.4	33.3	4.6	3.4
B		07:08:58	50	5	8	22.6			
B		07:11:38	50	6	7	23.2			
B		07:14:59	53	3	8	23.0			
B		07:18:21	52	3	8	23.4	30.7	1.7	1.4
B		07:21:11	52	6	7	22.9			
B		07:24:11	52	5	8	22.6			
B		07:27:01	52	4	6	22.7			
B/250		07:29:41	53	2	9	22.5			
C/252	2000'	07:35:38	51	5	10	23.8			
C		07:38:09	55	5	8	24.1			
C		07:41:08	55	2	7	24.5			
C		07:44:08		2	7	24.8			
C		07:46:39	46	4	10	24.4	21.1		
C		07:48:58	43	4	8	23.9			
C		07:51:58	42	5	8	23.7			
C		07:54:58	42	4	10	23.5			
C		07:57:00	43	5	9	23.3			
C/129		08:00:50	30	6	22	23.2			

* See flight map for Arc; Radial off Tulsa VOR.

Table B-7. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 22, 1985

Hydrocarbon	A/C Arc A 0637-0646 (CDT)	A/C Arc B 0704-0713 (CDT)	A/C Arc B 0717-0726 (CDT)	A/C Arc C 0743-0752 (CDT)
Ethane	7.4	8.7	9.1	6.3
Ethylene	(1.0)	(2.2)	(1.3)	(0.8)
Acetylene	0.6	0.7	0.4	0.5
Propane	5.3	8.3	7.0	4.2
Propene	0.3	0.1	0.1	0.1
i-Butane	1.3	2.4	1.8	1.0
n-Butane	3.0	5.4	4.1	2.4
i-Pentane	1.4	1.0	1.9	1.2
n-Pentane	1.1	0.9	1.4	0.8
Cyclopentane	0.2	-	0.1	-
Isoprene	-	0.3	0.1	-
2,3-Dimethylbutane	-	0.1	-	0.2
2-Methylpentane	0.4	0.3	0.3	0.5
3-Methylpentane	0.2	0.2	-	0.2
n-Hexane	0.4	-	-	0.5
Methylcyclopentane	0.2	0.1	0.2	0.2
Benzene	0.4	0.5	0.3	0.6
Cyclohexane	-	0.2	1.0	0.1
2-Methylhexane	-	0.2	0.2	0.1
3-Methylhexane	0.3	0.1	0.1	0.1
2,2,4-Trimethylpentane	-	0.1	0.4	0.2
Toluene	0.5	1.0	0.7	0.6
n-Octane	-	-	-	-
Ethylbenzene	0.1	0.1	0.2	0.1
p & *m*-Xylene	0.2	0.2	*	0.2
o-Xylene	0.2	0.2	*	0.2
Total Identified HC	24.5	33.3	30.7	21.1
TOTAL NMHC	24.5	41.6	37.8	21.1
% Paraffins	87	84	90	86
% Olefins	5	8	5	4
% Aromatics	6	6	4	8

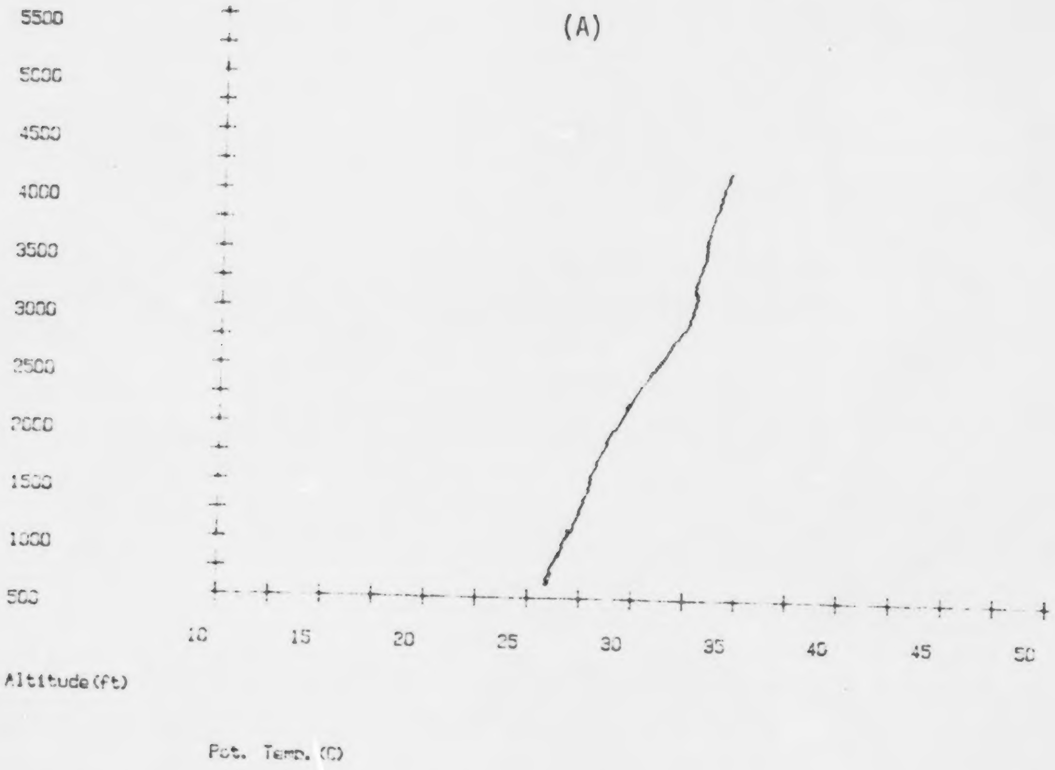
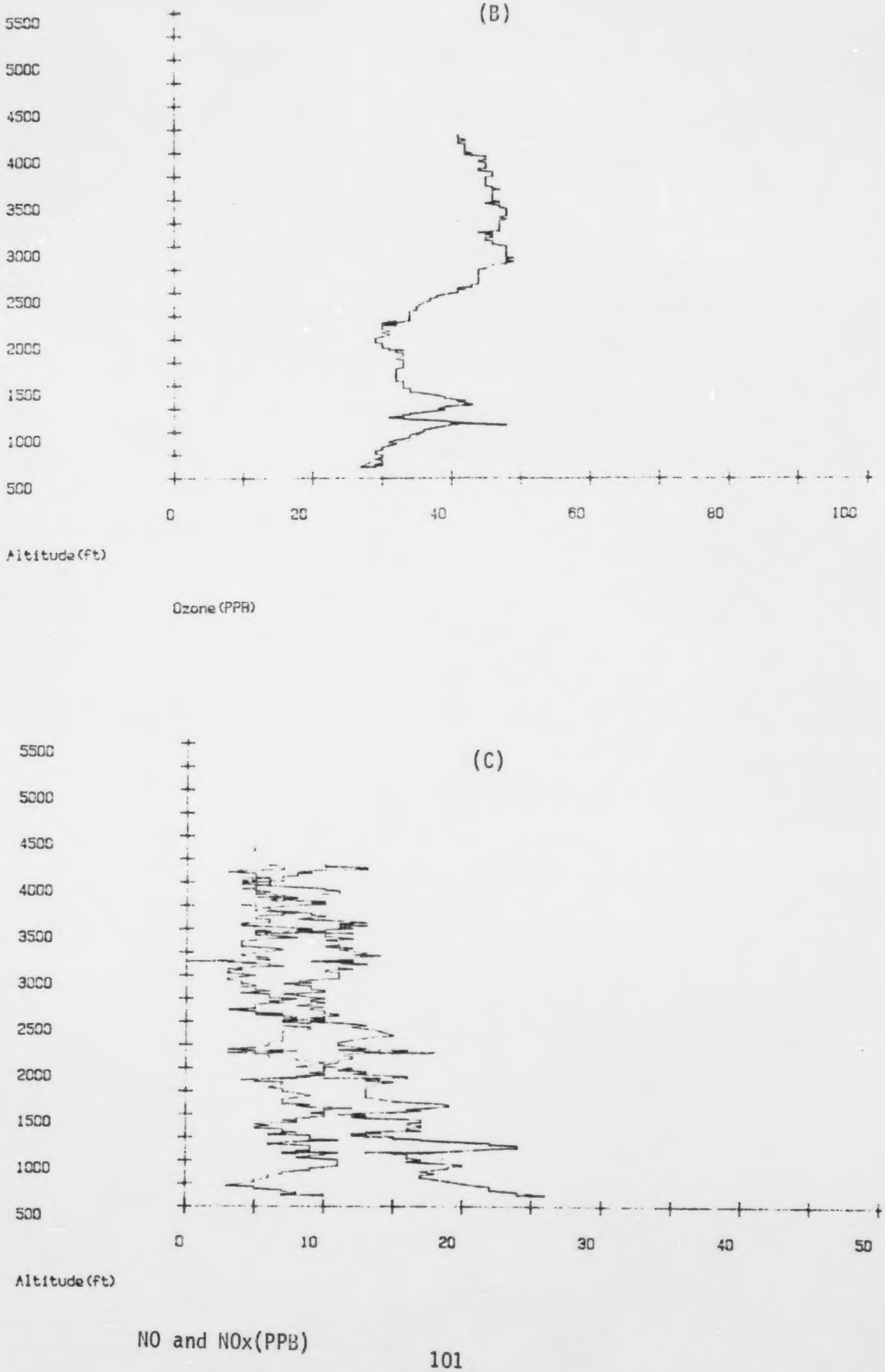


Figure B-14. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on July 22, 1985.

(Figure B-14. cont'd.)



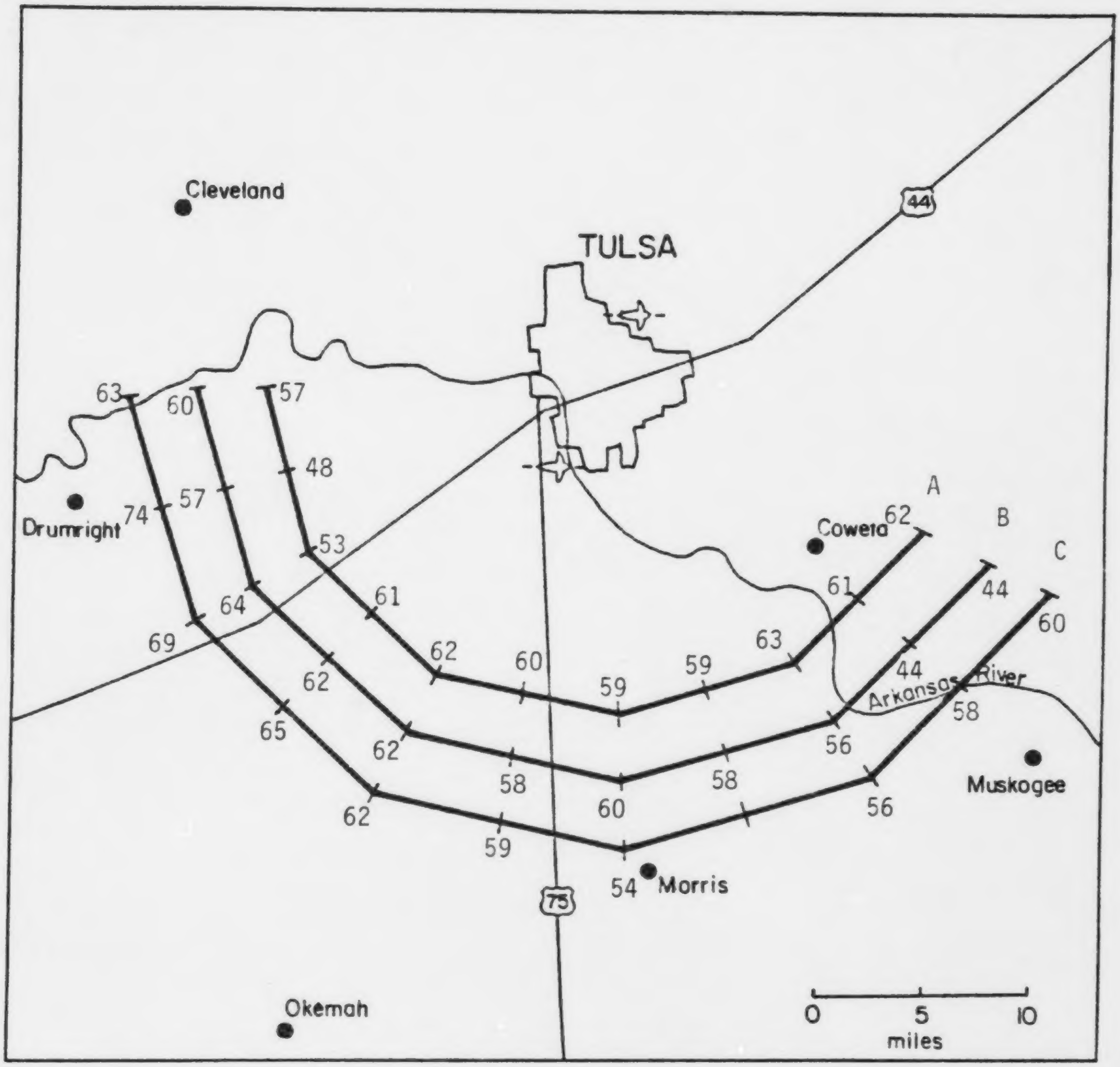

TULSA
Cleveland
Drumright
Coweta
Muskogee
Morris
Okemah
44
75
Arkansas River
A
B
C
63
74
69
65
62
59
54
60
57
64
62
62
58
60
58
56
56
58
60
57
48
53
61
62
60
59
59
63
61
62
44
44
0
5
10
miles

Figure R-15. July 23 flight path with ozone concentrations (ppb) marked along the route.

Time (CDT) and Altitude (AGL)

A: 0627 - 0657 at 2000'

B: 0658 - 0728 at 3000'

C: 0730 - 0801 at 2000'

Wind: light and variable

July 23, 1985

Morning Mixing Level: 1100 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/252		06:27:15	57	4	8	25.5			
A		06:30:25	48	3	15	25.4			
A		06:33:35	53	5	9	25.4			
A		06:36:25	61	7	10	25.4			
A		06:39:15	62	5	7	25.5			
A	2000'	06:42:15	60	7	10	25.5	46.3	5.3	0.9
A		06:45:16	59	6	10	25.3			
A		06:48:06	59	4	8	25.2			
A		06:51:06	63	7	11	24.9			
A		06:53:46	61	5	12	24.9			
A/129		06:56:16	62	4	11	24.9			
B/125		06:58:52	44	3	8	23.1			
B		07:01:42	44	7	18	23.0			
B		07:04:42	56	3	10	22.8			
B		07:07:42	58	4	9	22.6			
B	3000'	07:10:42	60	3	7	22.6	26.2	1.4	1.1
B		07:13:32		4	9	22.8			
B		07:16:22	62	3	8	22.9			
B		07:19:02	62	4	9	23.0			
B		07:21:42	64	5	11	23.2			
B		07:24:32	57	4	12	23.1			
B/250		07:27:02	60	6	10	23.2			
C/250		07:30:11	63	5	11	25.8			
C		07:32:51	74	4	8	25.9			
C		07:35:31	69	4	10	25.8	50.2	6.7	0.3
C		07:38:50	65	4	9	25.8			
C	2000'	07:42:00	62	6	10	25.6			
C		07:45:00	59	4	10	25.5			
C		07:47:40	54	7	13	25.2	78.0		
C		07:54:57	56	4	10	25.3			
C		07:57:57	58	6	8	25.3			
C/123		08:00:48	60	5	10	25.4			

* See flight map for Arc; Radial off Tulsa VOR.

Table D-8. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 23, 1985

Hydrocarbon	A/C Arc A 0639-0648 (CDT)	A/C Arc B 0709-0715 (CDT)	A/C Arc C 0733-0742 (CDT)	A/C Arc C 0746-0755 (CDT)
Ethane	15.3	8.5	15.3	21.9
Ethylene	(2.1)	(1.2)	(2.2)	(4.0)
Acetylene	0.7	0.7	0.6	0.6
Propane	11.8	6.5	12.3	22.0
Propene	0.3	-	0.7	0.3
i-Butane	2.4	1.5	2.5	3.9
n-Butane	5.7	2.9	6.2	11.7
i-Pentane	1.9	1.1	1.9	3.6
n-Pentane	1.9	0.9	2.1	4.1
Cyclopentane	-	0.2	0.2	0.2
Isoprene	0.1	0.1	0.1	-
2,3-Dimethylbutane	-	-	-	0.2
2-Methylpentane	0.4	0.3	0.7	1.1
3-Methylpentane	0.3	0.2	0.4	0.6
n-Hexane	0.7	-	0.8	1.3
Methylcyclopentane	0.3	0.2	0.3	0.6
Benzene	0.5	0.5	1.0	0.5
Cyclohexane	0.2	0.1	0.2	-
2-Methylhexane	0.2	0.1	0.2	0.2
3-Methylhexane	0.3	0.3	0.3	-
2,2,4-Trimethylpentane	0.1	0.1	0.2	-
Toluene	0.5	0.4	0.8	0.4
n-Octane	0.1	0.1	-	0.3
Ethylbenzene	0.1	-	0.3	0.2
p & *m*-Xylene	0.2	0.2	0.4	0.2
o-Xylene	0.2	0.1	0.5	0.1
Total Identified HC	46.3	26.2	50.2	78.0
TOTAL NMHC	47.0	26.2	58.3	78.4
% Paraffins	90	86	87	91
% Olefins	5	6	6	6
% Aromatics	3	5	6	2

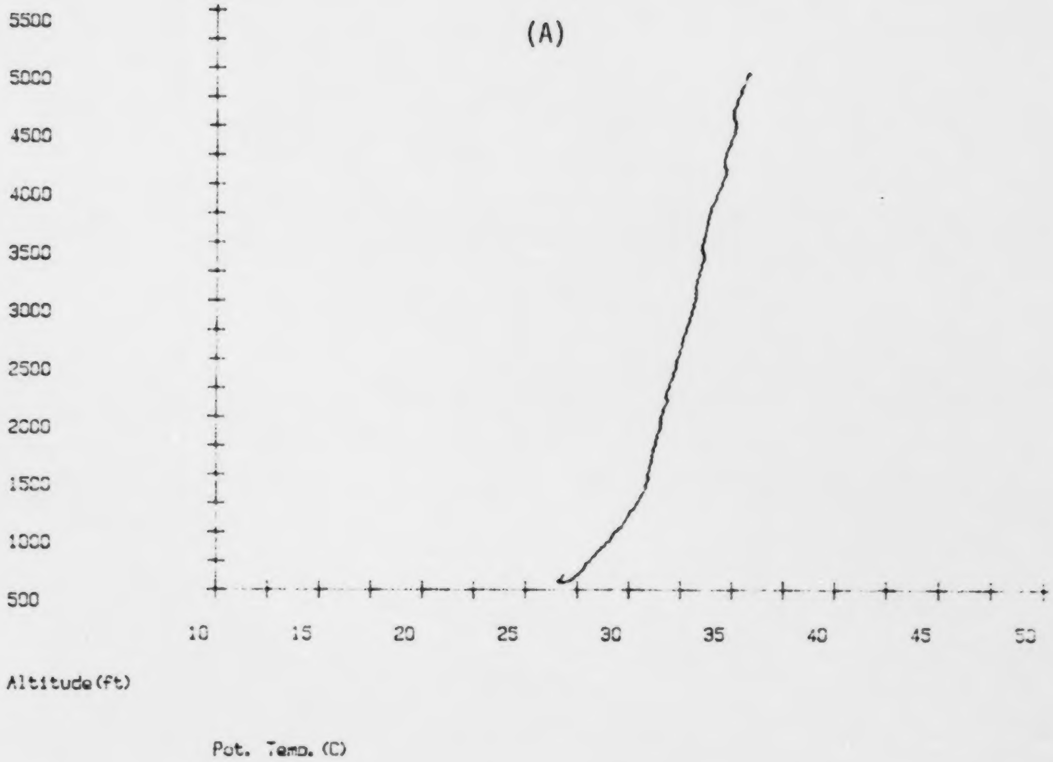
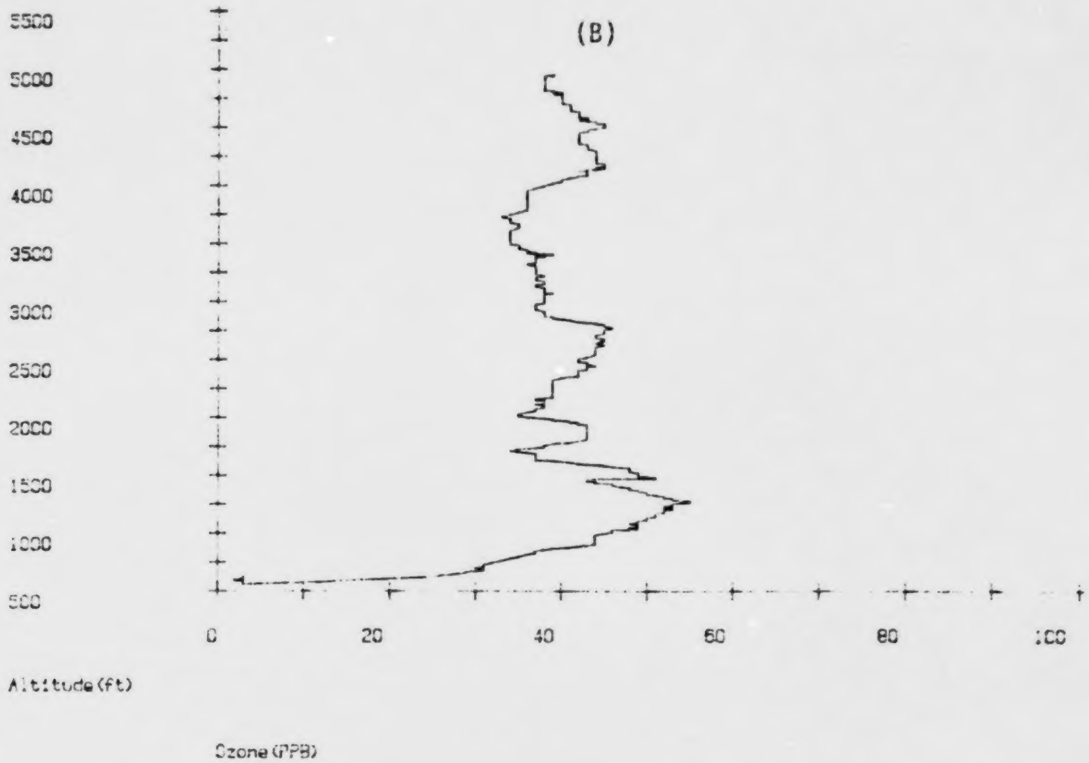
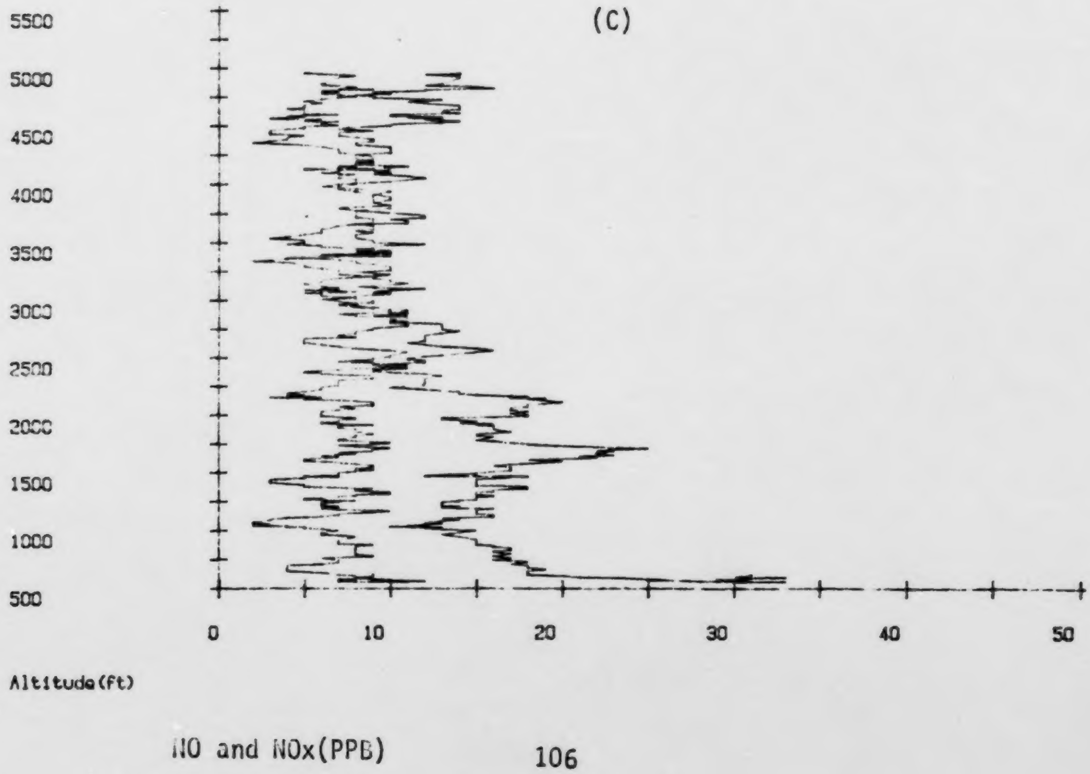


Figure B-16. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on July 23, 1985.

(Figure B-16. cont'd.)





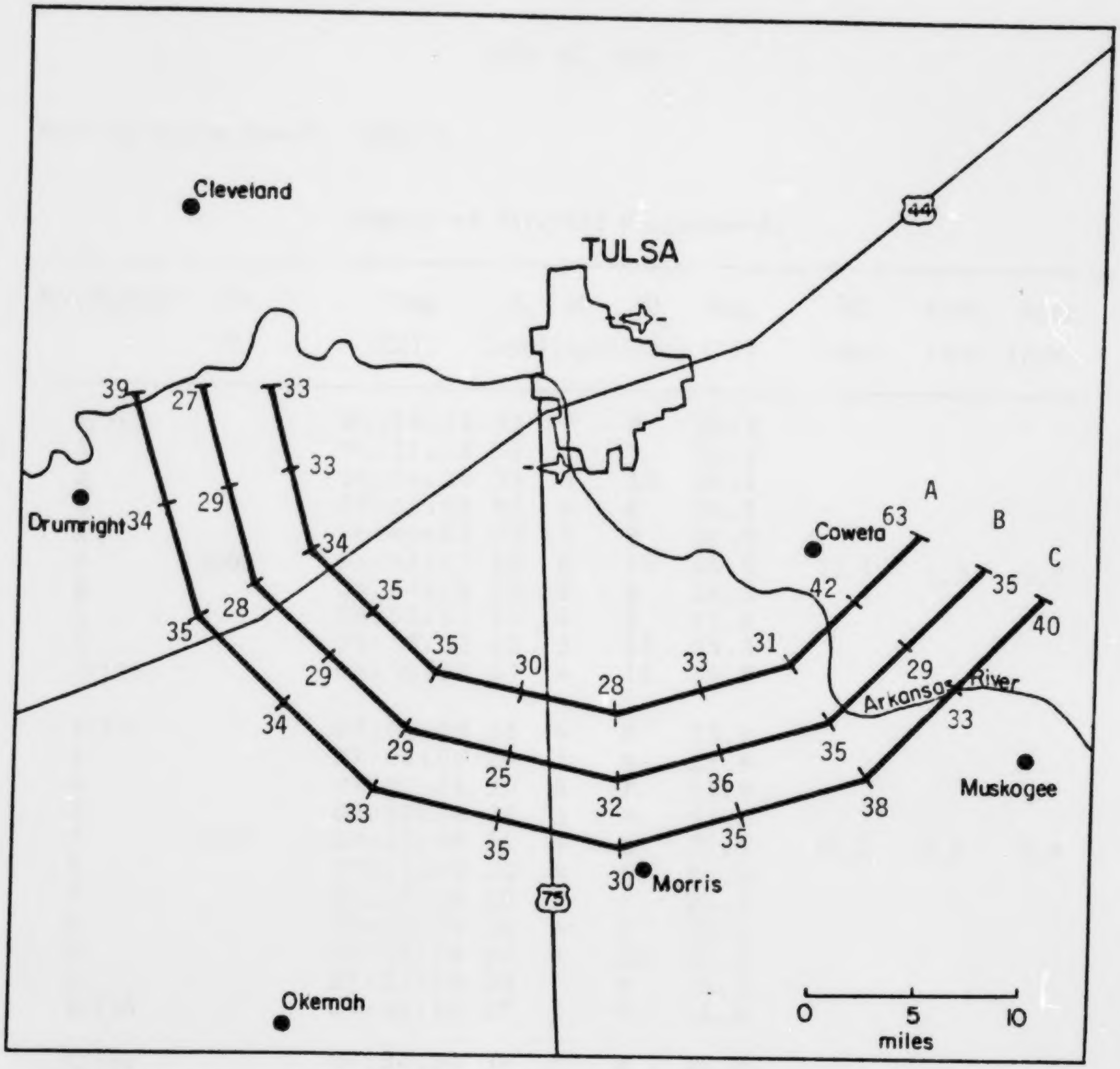

Cleveland
TULSA
44
Drumright
Coweta
A
B
C
Arkansas River
Muskogee
Morris
75
Okemah
39
27
33
33
29
34
34
35
28
35
35
29
30
28
33
31
42
63
35
29
40
33
34
29
25
36
35
32
38
33
35
35
30
0
5
10
miles

Figure B-17. July 24 flight path with ozone concentrations (ppb) marked along the route.

Time (CDT) and Altitude (AGL)

A: 0628 - 0657 at 2000'

B: 0701 - 0731 at 3000'

C: 0734 - 0803 at 2000'

Wind: 190° at 17 knots

July 24, 1985

Morning Mixing Level: 1300 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/252		06:28:28	33	7	8	26.3			
A		06:31:18	34	3	7	26.2			
A		06:34:38	35	6	10	26.1			
A		06:37:58	35	4	8	26.1			
A		06:40:42	30	5	8	26.0			
A	2000'	06:43:22	28	6	10	26.0	12.4	1.9	<0.2
A		06:47:12	33	5	9	26.0			
A		06:50:52	31	4	8	25.6			
A		06:53:32	42	3	15	25.3			
A/129		06:56:13	63	4	12	24.8			
B/125		07:01:08	35	6	8	23.1			
B		07:04:08	29	5	9	23.8			
B		07:07:18	35	6	7	23.9			
B		07:10:38	36	5	9	23.8			
B	3000'	07:13:58	32	4	8	23.9	22.1	5.0	1.4
B		07:16:49	25	4	6	24.0			
B		07:19:29	29	3	7	24.3			
B		07:22:19	29	4	9	24.1			
B		07:25:19	28	5	10	24.1			
B		07:27:59	29	4	8	24.1			
B/250		07:30:30	27	5	7	24.0			
C/250		07:34:32	39	5	9	26.0			
C		07:37:03	34	5	10	26.1			
C		07:39:34	35	4	9	25.9	23.3		
C		07:42:44	34	3	10	26.0			
C	2000'	07:45:54	33	6	7	25.9		2.7	<0.2
C		07:48:44	35	4	8	25.8			
C		07:51:24	30	3	11	25.8	16.1		
C		07:54:14	35	5	8	25.8			
C		07:57:14	38	4	10	25.8			
C		07:59:54	33	6	8	25.9			
C/123		08:02:34	40	4	11	25.3			

* See flight map for Arc; Radial off Tulsa VOR.

Table B-9. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 24, 1985

Hydrocarbon	A/C Arc A 0636-0645 (CDT)	A/C Arc B 0712-0721 (CDT)	A/C Arc C 0737-0746 (CDT)	A/C Arc C 0749-0758 (CDT)
Ethane	3.0	4.9	5.9	4.0
Ethylene	(0.4)	(0.9)	(1.0)	(0.6)
Acetylene	0.2	0.5	0.6	0.4
Propane	2.3	5.0	5.4	3.6
Propene	0.2	0.5	-	-
i-Butane	1.0	1.5	1.7	1.4
n-Butane	1.7	3.1	3.0	1.8
i-Pentane	0.7	1.5	1.5	1.0
n-Pentane	0.5	1.3	1.1	0.7
Cyclopentane	-	-	0.3	-
Isoprene	-	0.6	0.3	-
2,3-Dimethylbutane	-	-	-	-
2-Methylpentane	0.2	0.3	0.3	0.2
3-Methylpentane	0.2	0.2	0.3	-
n-Hexane	-	0.3	0.3	-
Methylcyclopentane	0.1	0.1	0.2	-
Benzene	0.4	0.4	0.4	0.5
Cyclohexane	-	0.1	-	-
2-Methylhexane	-	-	-	-
3-Methylhexane	0.2	0.3	0.3	0.5
2,2,4-Trimethylpentane	-	-	-	0.1
Toluene	0.5	0.3	0.3	0.8
n-Octane	-	-	0.1	0.1
Ethylbenzene	0.3	0.1	0.1	*
p & *m*-Xylene	0.2	-	0.1	0.2
o-Xylene	0.3	0.2	0.1	0.2
Total Identified HC	12.4	22.1	23.3	16.1
TOTAL NMHC	17.4	24.1	25.3	27.7
% Paraffins	89	84	87	83
% Olefins	5	9	6	4
% Aromatics	14	5	4	11

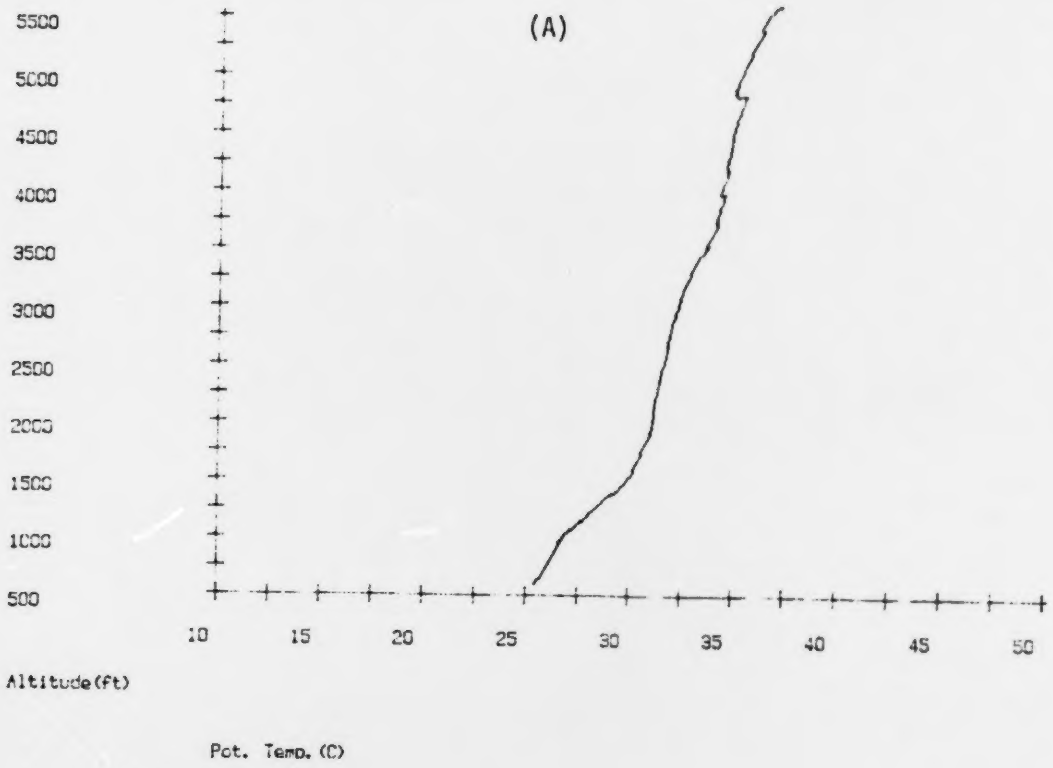
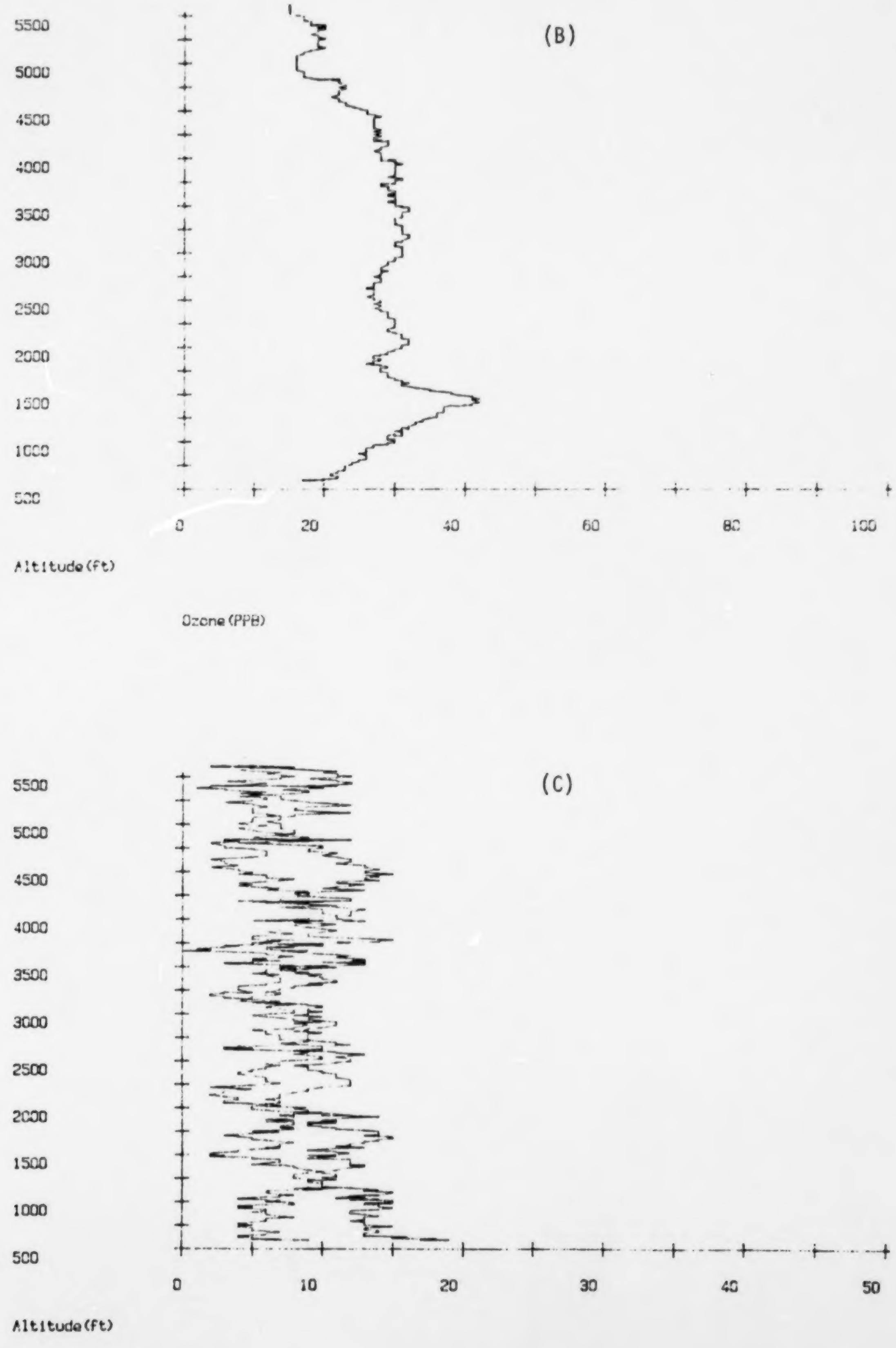


Figure B-18. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on July 24, 1985.

(Figure B-18. cont'd.)



NO and NOx(PPB)

APPENDIX C

Aircraft Flight Maps and Pollutant Measurement Data Obtained from Atlanta, Georgia

ATLANTA AIR QUALITY DATA

This section provides a tabulation of airborne data collected in the Atlanta area during the period August 13-23, 1985. For each sampling day, there is a flight map with ozone concentrations marked along the route, a tabulation of air quality data, a listing of individual hydrocarbon concentrations and a graphical summary of ozone, NO_x and temperature changes with altitude. On August 21 and August 23 there was no reported wind: a complete circumnavigation of the city was done.

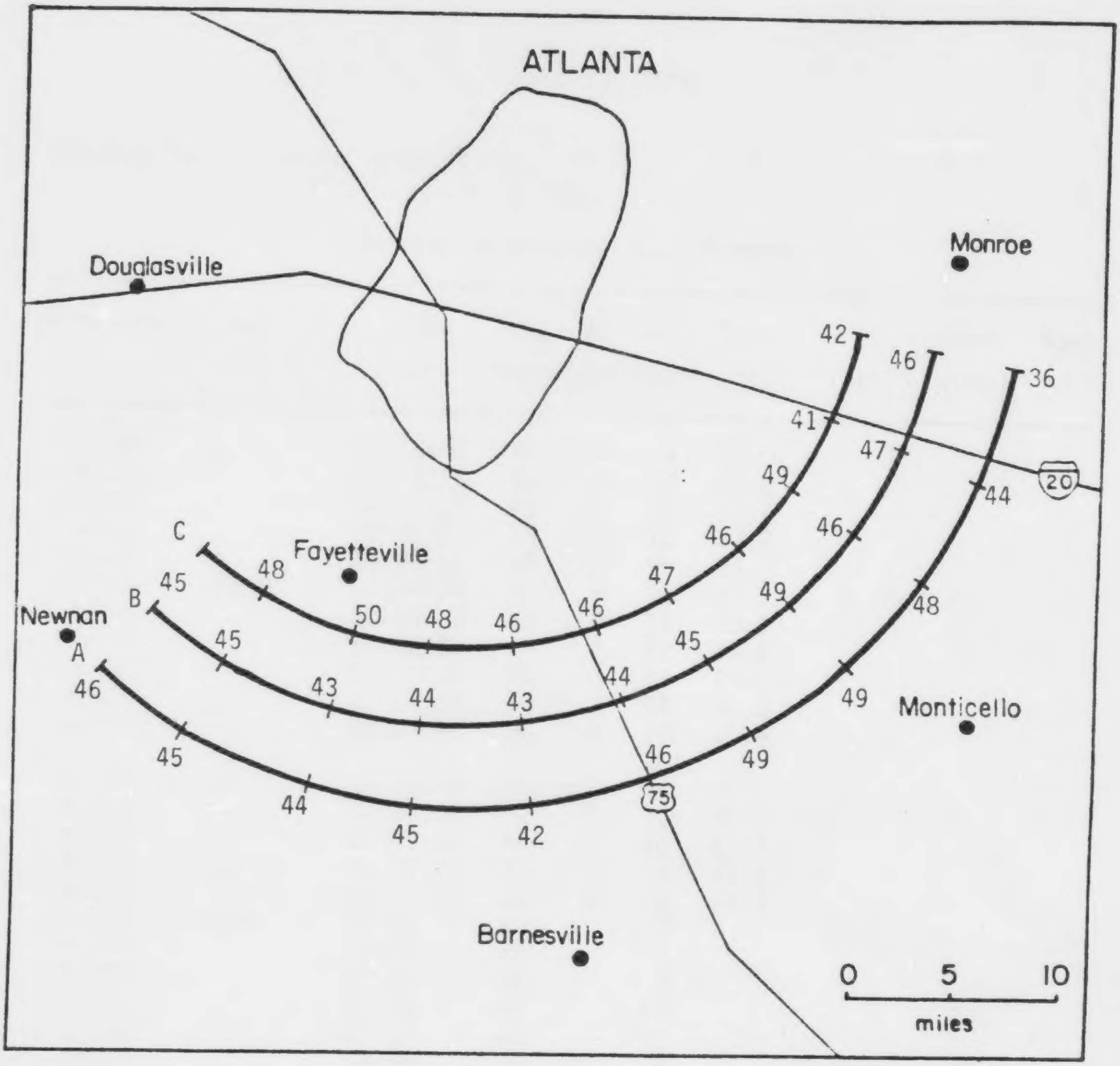
NOTES on Hydrocarbon Tables

* Means data not available

- Means concentration less than 0.1 ppbC

( ) Ethylene values in parentheses were calculated by multiplying the propane concentration by 0.18. This was necessary in cases of obvious ethylene contamination due to the presence of a chemiluminescent ozone analyzer. The ethylene-propane ratio was derived from airborne samples that were free of contamination problems.

TNMHC is the sum of all gas chromatographic peaks



ATLANTA
Douglasville
Monroe
Fayetteville
Newnan
Monticello
Barnesville
C
B
A
20
75
42
46
36
41
47
44
49
46
46
48
49
47
46
48
45
50
48
46
46
45
45
43
44
43
44
49
46
46
45
44
45
42
46
49
0
5
10
miles

Figure C-1. August 13 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude

A: 0652 - 0721 at 3000'
B: 0725 - 0755 at 4000'
C: 0801 - 0830 at 3000'

Wind: 160° at 7 knots

August 13, 1985

Morning Mixing Level: 1725 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/220	3000'	06:52:46	46	4	9	24.0	25.6	<0.7	1.2
A/208		06:55:26	45	4	12	23.8			
A/196		06:58:17	44	1	11	23.7			
A/184		07:00:57	45	2	11	23.7			
A/172		07:03:48	42	5	16	23.7			
A/160		07:06:38	46	3	11	23.9			
A/148		07:09:18	49	3	11	23.9			
A/136		07:12:08	49	5	12	24.0			
A/124		07:14:48	48	2	10	24.1			
A/112		07:17:38	44	2	12	24.0			
A/100		07:20:18	36	4	10	23.9			
B/100	4000'	07:25:33	46	3	11	22.2	10.4	<0.8	1.5
B/112		07:28:24	47	2	10	21.9			
B/124		07:31:24	46	2	10	21.7			
B/136		07:34:14	44	2	9	21.6			
B/148		07:37:14	45	2	10	21.3			
B/160		07:40	44		7				
B/172		07:43	43		8				
B/184		07:46	44		9				
B/196		07:49	43		10				
B/208		07:52	45		11				
B/220		07:55	45		8				
C/220	3000'	08:01					10.6		0.8
C/208		08:04:22	48	4	9	23.4			
C/196		08:07:12	50	2	10	23.3			
C/184		08:09:52	48	4	10	23.2			
C/172		08:12:52	46	3	10	22.3			
C/160		08:15:32	46	3	11	22.3			
C/148		08:18	47		10				
C/136		08:21	46		8				
C/124		08:24	44		8				
C/112		08:27	41		9				
C/100		08:30	42		7				

* See flight map for Arc; Radial off Atlanta City Center.

Table C-1. Hydrocarbon Concentrations (ppbC) in Samples Collected on August 13, 1985

Hydrocarbon	A/C Arc A 0702 - 0711 (EDT)	A/C Arc B 0735 - 0744 (EDT)	A/C Arc C 0811 - 0820 (EDT)
Ethane	7.2	2.6	2.6
Ethylene	(0.1)	(0.2)	(0.2)
Acetylene	0.8	0.3	0.2
Propane	0.5	1.3	1.3
Propene	1.5	0.7	0.2
i-Butane	1.1	0.3	0.3
n-Butane	1.7	1.1	1.1
i-Pentane	0.8	0.9	1.0
n-Pentane	0.4	0.3	0.3
Cyclopentane	0.6	0.3	0.3
Isoprene	3.1	-	0.1
2,3-Dimethylbutane	0.1	-	0.1
2-Methylpentane	0.2	0.2	0.2
3-Methylpentane	-	-	0.1
n-Hexane	0.2	-	0.1
Methylcyclopentane	0.1	-	0.1
Benzene	0.5	0.4	0.5
Cyclohexane	1.6	-	-
2-Methylhexane	0.1	-	0.1
3-Methylhexane	0.7	0.3	-
2,2,4-Trimethylpentane	0.7	-	0.3
Toluene	1.2	0.9	0.9
n-Octane	-	-	0.1
Ethylbenzene	0.7	0.1	0.2
p & *m*-Xylene	1.0	0.2	0.2
o-Xylene	0.7	0.3	0.1
Total Identified HC	25.6	10.4	10.6
TOTAL NMHC	47.9	10.4	14.9
% Paraffins	63	70	75
% Olefins	18	9	5
% Aromatics	16	18	18

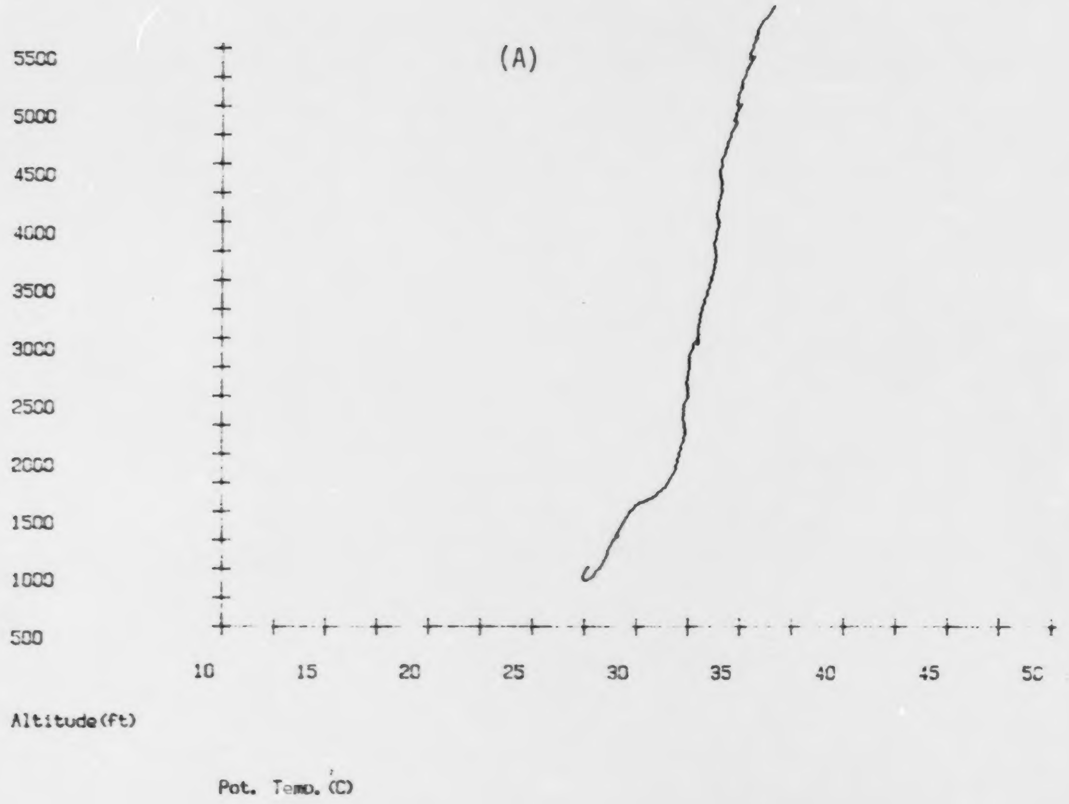
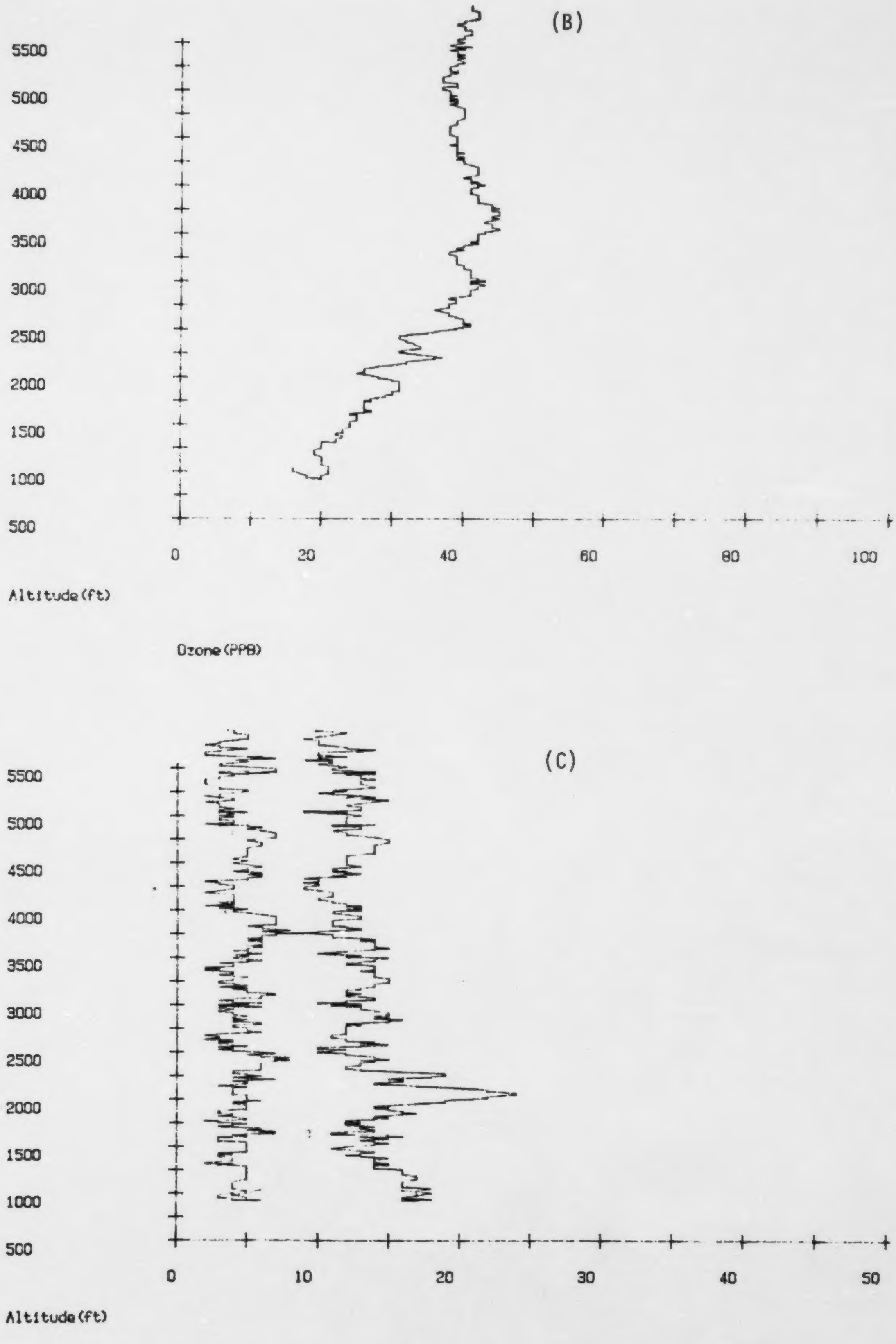


Figure C-2. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on August 13, 1985.

(Figure C -2. cont'd.)



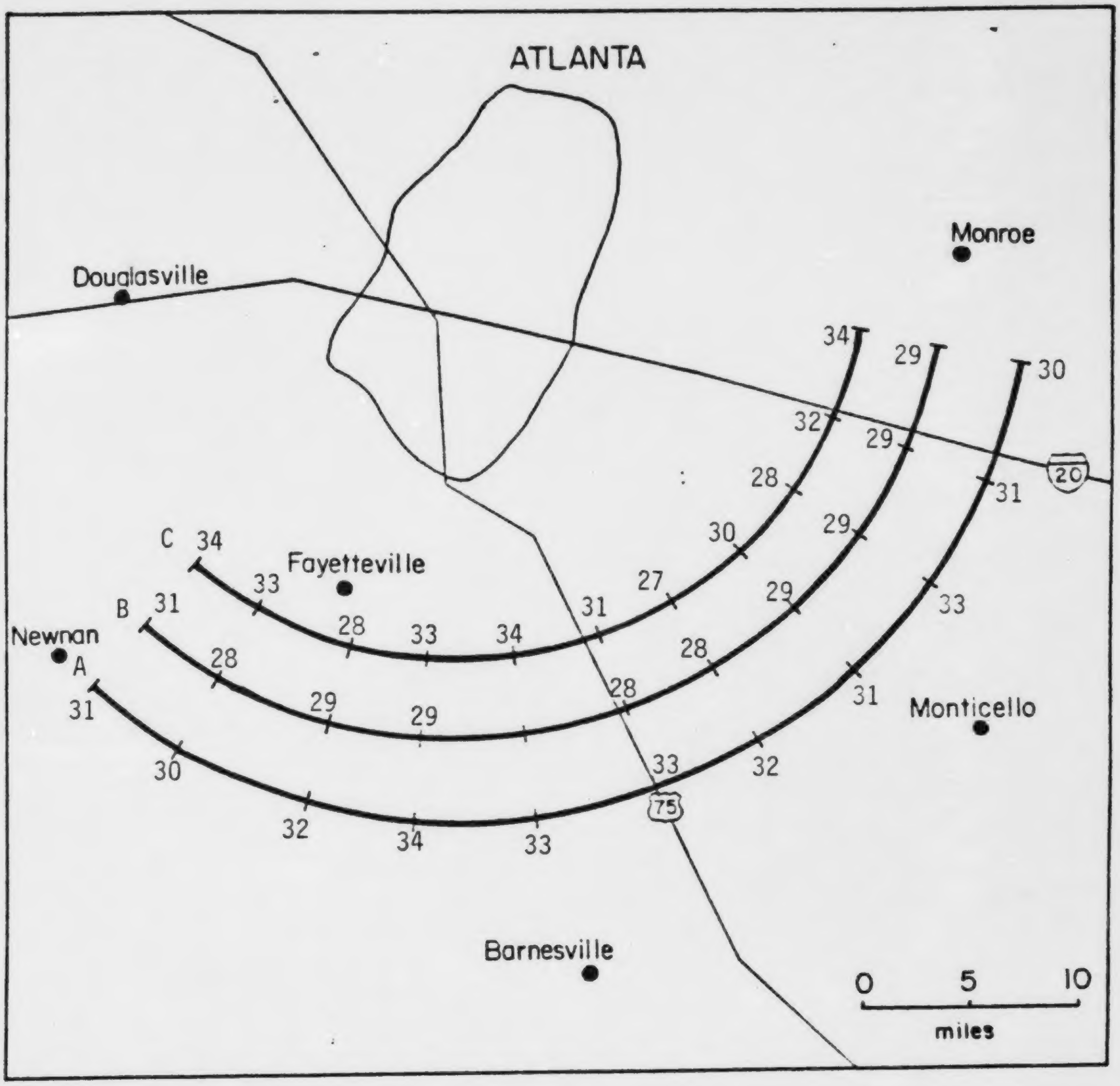

ATLANTA
Monroe
Douglasville
Fayetteville
Newnan
Monticello
Barnesville
20
75
A
B
C
A: 31 30 32 34 33 33 32 31 33 31 30
B: 31 28 29 29 28 28 29 29 29 29
C: 34 33 28 33 34 31 27 30 28 32 34
0 5 10
miles

Figure C-3. August 15 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude

A: 0420 - 0451 at 3000'
B: 0456 - 0525 at 4000'
C: 0529 - 0558 at 3000'.

Wind: 160° at 15 knots

August 15, 1985

Morning Mixing Level: 1000 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/220		04:21:49	31	4	9	21.9			
A/208		04:24:40	30	2	11	22.1			
A/196		04:27:30	32	5	7	22.3			
A/184		04:30:20	34	5	12	22.8			
A/172		04:33:11	33	4	9	23.1			
A/160	3000'	04:36:11	33	2	8	23.3	7.0	<0.7	<0.7
A/148		04:39:01	32	4	8	23.6			
A/136		04:42:01	31	5	7	23.3			
A/124		04:44:51	33	4	10	23.0			
A/112		04:47:41	31	6	9	22.0			
A/100		04:50:31	30	4	10	22.4			
B/100		04:56:43	29	3	6	20.7			
B/112		04:59:25	29	4	9	21.2			
B/124		05:02:16	29	2	8	21.0			
B/136		05:05:06	28	4	8	20.6			
B/148		05:07:56	28	4	8	20.9			
B/160	4000'	05:11	28		8		92.6	<0.7	1.0
B/172		05:13			5				
B/184		05:16	29		6				
B/196		05:19:05	29	4	6	20.5			
B/208		05:21:55	28	2	6	21.0			
B/220		05:24:37	31	3	7	21.1			
C/220		05:29:41	34	3	7	21.9			
C/208		05:32:31	33	3	6	21.6			
C/196		05:35:32	28	3	8	21.5			
C/184		05:38:12	33	5	6	21.9			
C/172		05:41:02	34	2	8	22.3	3.1		
C/160	3000'	05:43:52	31	3	9	22.0		<0.7	<0.3
C/148		05:46:42	27	3	6	21.7	2.4		
C/136		05:49:32	30	4	8	21.6			
C/124		05:52:22	28	4	8	21.6			
C/112		05:55:13	32	3	10	21.8			
C/100		05:58	34		7				

* See flight map for Arc; Radial off Atlanta City Center.

Table C-2. Hydrocarbon Concentrations (ppbC) in Samples Collected on August 15, 1985

Hydrocarbon	A/C Arc A 0432 - 0441 (EDT)	A/C Arc B 0507 - 0516 (EDT)	A/C Arc C 0539 - 0548 (EDT)	A/C Arc C 0553 - 0554 (EDT)
Ethane	1.9	4.8	1.6	1.4
Ethylene	-	(0.4)	-	-
Acetylene	0.1	0.4	-	-
Propane	0.3	2.4	0.2	0.3
Propene	0.1	0.6	0.2	-
i-Butane	0.2	1.8	-	-
n-Butane	0.4	5.2	-	0.4
i-Pentane	0.7	20.2	0.1	-
n-Pentane	0.3	4.8	-	-
Cyclopentane	-	0.4	-	-
Isoprene	-	1.1	-	-
2,3-Dimethylbutane	-	2.7	-	-
2-Methylpentane	0.2	2.3	-	-
3-Methylpentane	-	1.2	-	-
n-Hexane	0.1	1.0	-	-
Methylcyclopentane	-	0.6	-	-
Benzene	0.3	1.3	0.2	0.1
Cyclohexane	-	0.3	-	-
2-Methylhexane	-	2.1	-	-
3-Methylhexane	0.3	0.6	0.2	-
2,2,4-Trimethylpentane	-	13.7	-	-
Toluene	0.9	16.5	0.3	0.2
n-Octane	-	0.8	-	-
Ethylbenzene	-	1.6	-	-
p & *m*-Xylene	0.9	3.7	0.1	-
o-Xylene	0.3	2.1	0.2	-
Total Identified HC	7.0	92.6	3.1	2.4
TOTAL NMHC	7.0	137.2	3.1	2.4
% Paraffins	64	71	68	87
% Olefins	1	2	6	-
% Aromatics	34	27	26	13

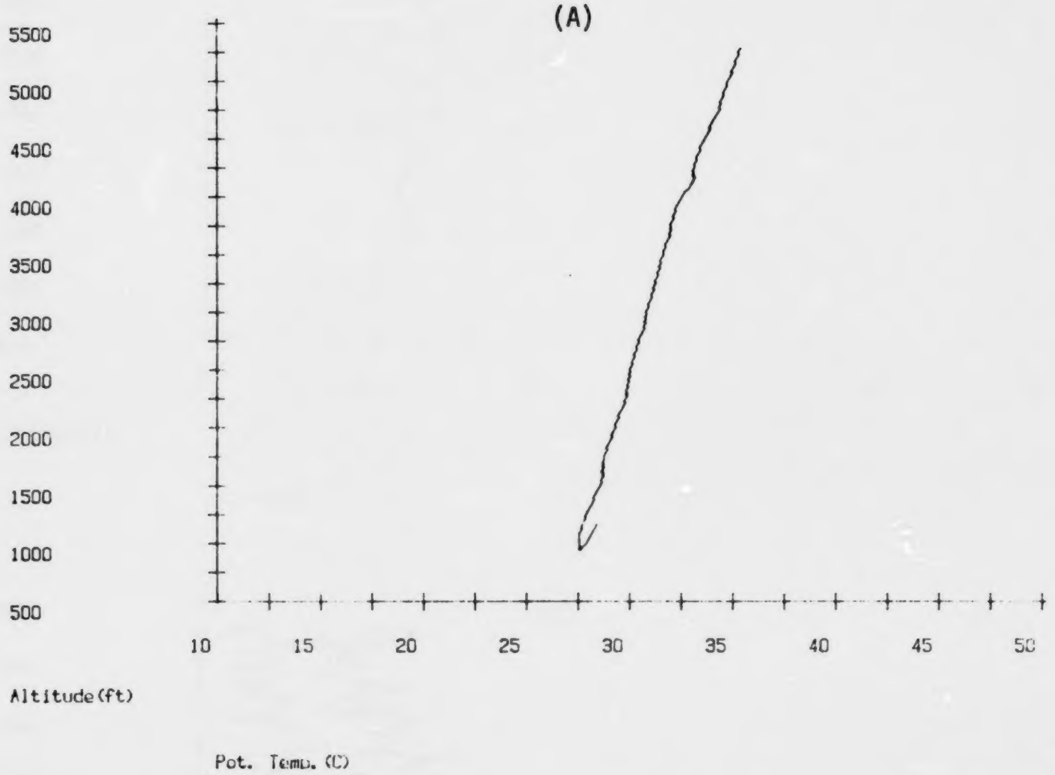
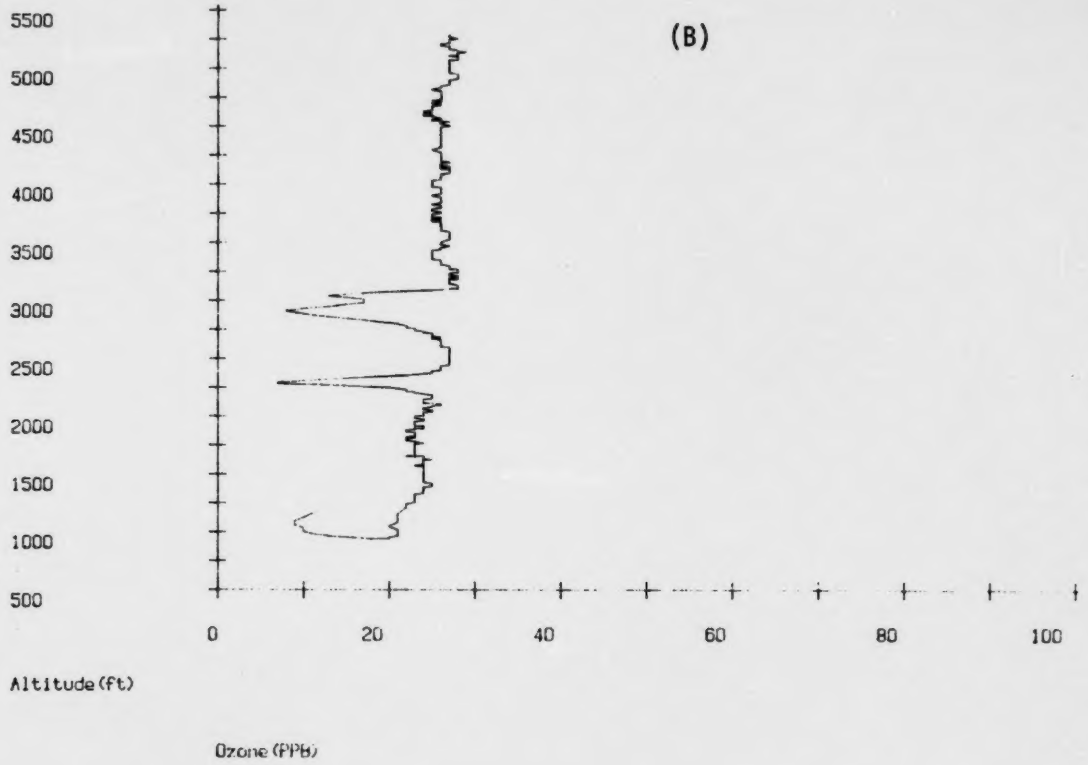
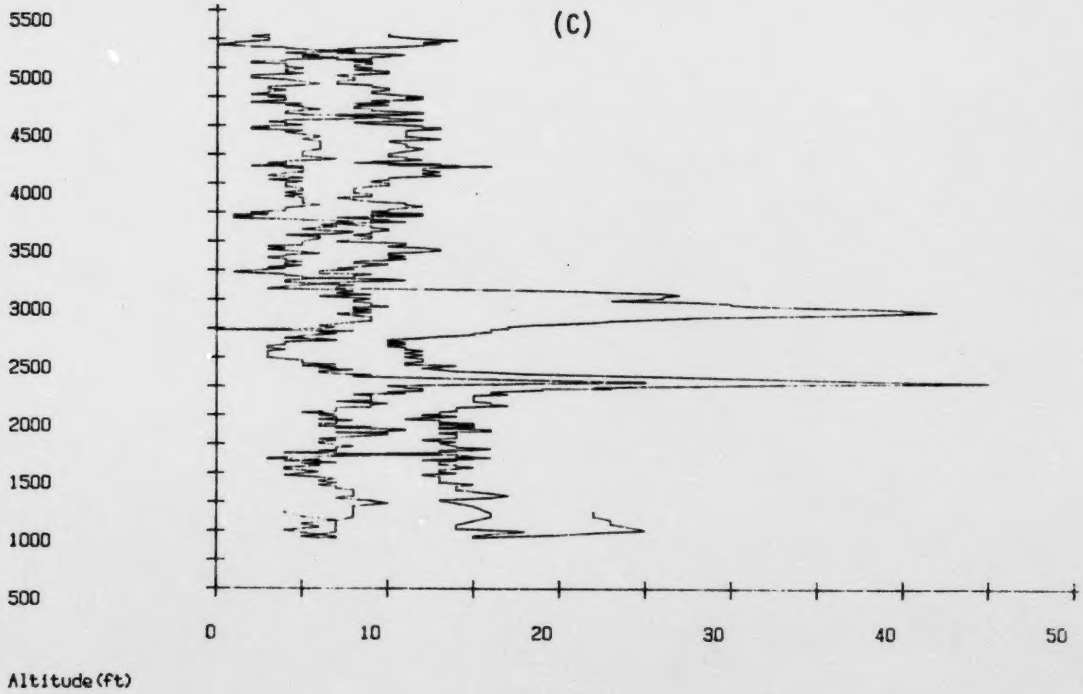
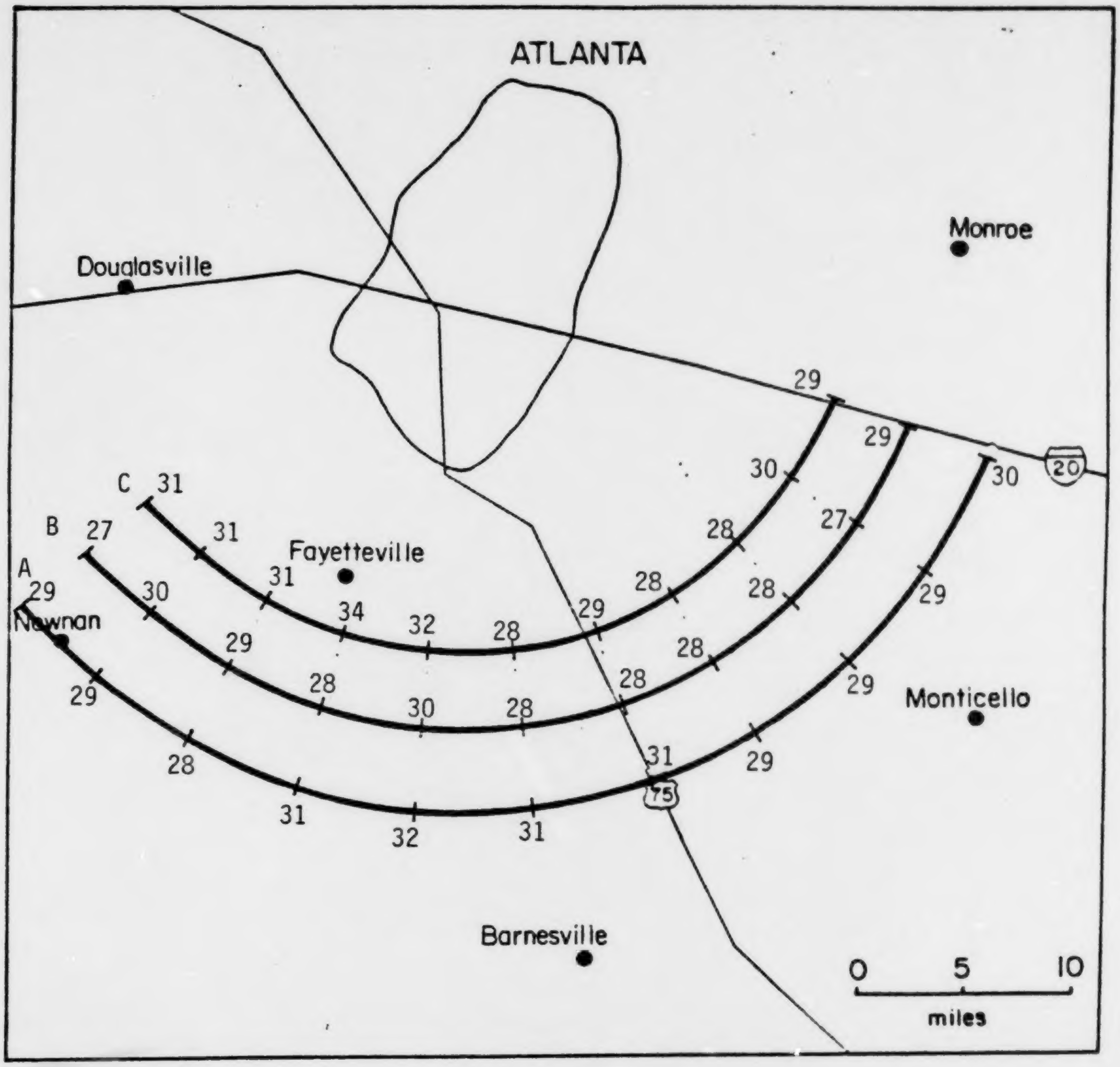


Figure C-4. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on August 15, 1985.

(Figure C-4. cont'd.)






ATLANTA
Monroe
Douglasville
29
29
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20
30
28
27
C
31
B
27
31
Fayetteville
A
29
30
31
28
28
29
34
32
28
29
Newnan
29
28
29
28
30
28
28
29
Monticello
29
31
75
28
31
32
31
Barnesville
0
5
10
miles

Figure C-5. August 16 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude

A: 0444 - 0517 at 3000'
B: 0524 - 0552 at 4000'
C: 0557 - 0652 at 3000'

Wind: 170° at 5 knots

August 16, 1985

Morning Mixing Level: 2020 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/230		04:44:48	29	4	12	23.8			
A/218		04:51:24	29	5	9	24.0			
A/206		04:54:15	28	5	10	24.2			
A/164		04:57	31		9				
A/182		05:00	32		11				
A/170	3000'	05:02:46	31	5	12	24.1	35.1		
A/158		05:05:46	31	5	11	24.1			
A/146		05:08:36	29	5	11	23.3			
A/134		05:11:26	29	5	10	23.5			
A/122		05:14:16	29	6	12	23.2			
A/110		05:16:58	30	5	10	23.3			
B/110		05:24:04	29	2	10	20.9			
B/122		05:26:44	27	4	9	20.4			
B/134		05:29:34	28	3	9	21.0			
B/146		05:32:24	28	3	10	21.4			
B/158		05:35:05	28	5	10	21.4			
B/170	4000'	05:37:56	28	4	10	21.3	28.2	<0.7	<0.3
B/182		05:40:46	30	2	12	21.5			
B/194		05:44	28		9				
B/206		05:46	29		8				
B/218		05:49	30		9				
B/230		05:52	27		6				
C/230		05:57	31		7				
C/218		06:00	31		8				
C/206		06:03	31		8				
C/194		06:06	34		9				
C/182		06:08	32		7		19.8		
C/170	3000'	06:11	28		8			<0.7	<0.3
C/158		06:14	29		9		32.0		
C/146		06:17	28		9				
C/134		06:20	28		9				
C/122		06:22	30		9				
C/110		06:25	29		8				

* See flight map for Arc; Radial off Atlanta City Center.

Table C-3. Hydrocarbon Concentrations (ppbC) in Samples Collected on August 16, 1985

Hydrocarbon	A/C Arc A 0457 - 0506 (EDT)	A/C Arc B 0534 - 0543 (EDT)	A/C Arc C 0547 - 0548 (EDT)	A/C Arc C 0607 - 0616 (EDT)
Ethane	10.5	1.8	2.4	2.6
Ethylene	(0.9)	(0.1)	(0.2)	(0.4)
Acetylene	0.4	0.2	0.3	0.3
Propane	5.0	0.8	1.3	2.0
Propene	1.1	-	0.4	0.2
i-Butane	1.0	0.4	0.3	0.4
n-Butane	3.1	0.7	1.0	1.2
i-Pentane	2.2	1.2	0.6	0.9
n-Pentane	1.2	0.6	0.2	0.3
Cyclopentane	0.4	0.4	0.3	1.0
Isoprene	1.0	1.0	0.8	0.9
2,3-Dimethylbutane		0.1	-	0.2
2-Methylpentane	0.4	0.5	0.2	0.7
3-Methylpentane	0.3	0.3	0.1	0.4
n-Hexane	0.3	0.2	0.2	0.7
Methylcyclopentane	0.2	0.2	-	0.4
Benzene	0.6	0.3	0.4	1.0
Cyclohexane	-	-	-	0.2
2-Methylhexane	0.3	0.5	0.2	0.7
3-Methylhexane	0.2	0.5	0.3	0.5
2,2,4-Trimethylpentane	0.4	0.6	-	1.0
Toluene	4.2	14.5	9.4	12.0
n-Octane	0.4	1.3	0.2	-
Ethylbenzene	0.3	0.3	0.3	1.0
p & *m*-Xylene	0.5	1.0	0.4	2.0
o-Xylene	0.2	0.7	0.3	1.0
Total Identified HC	35.1	28.2	19.8	32.0
TOTAL NMHC	35.9	33.9	21.3	38.0
% Paraffins	73	35	38	41
% Olefins	9	4	7	5
% Aromatics	17	60	54	53

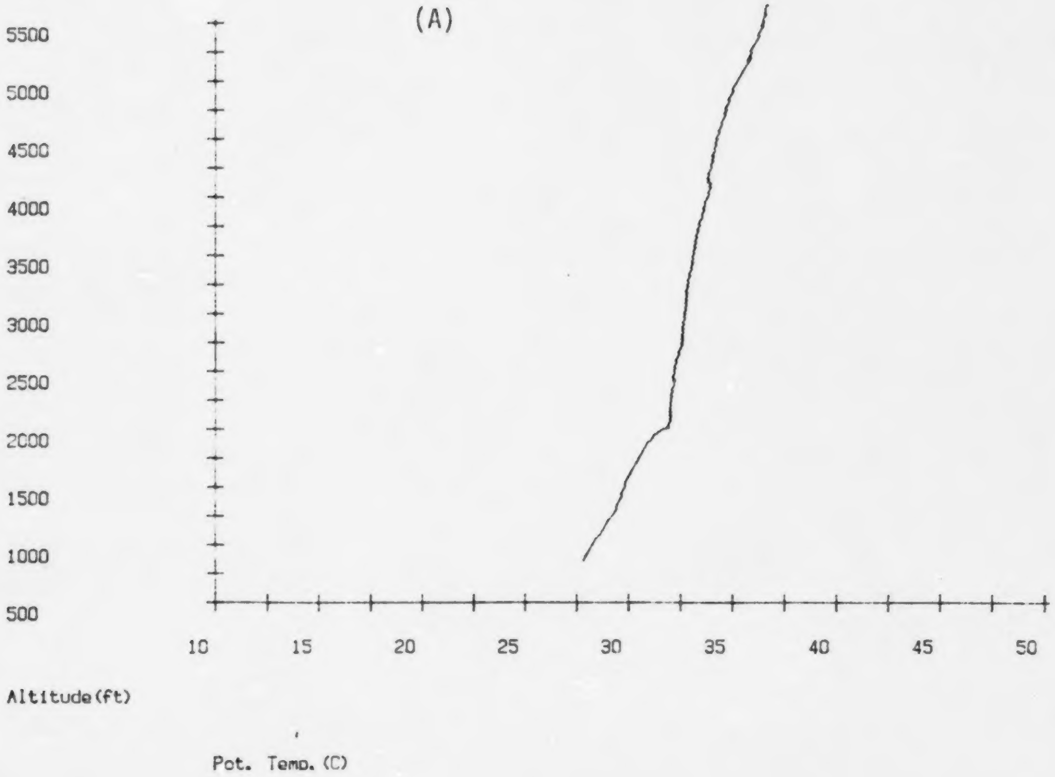
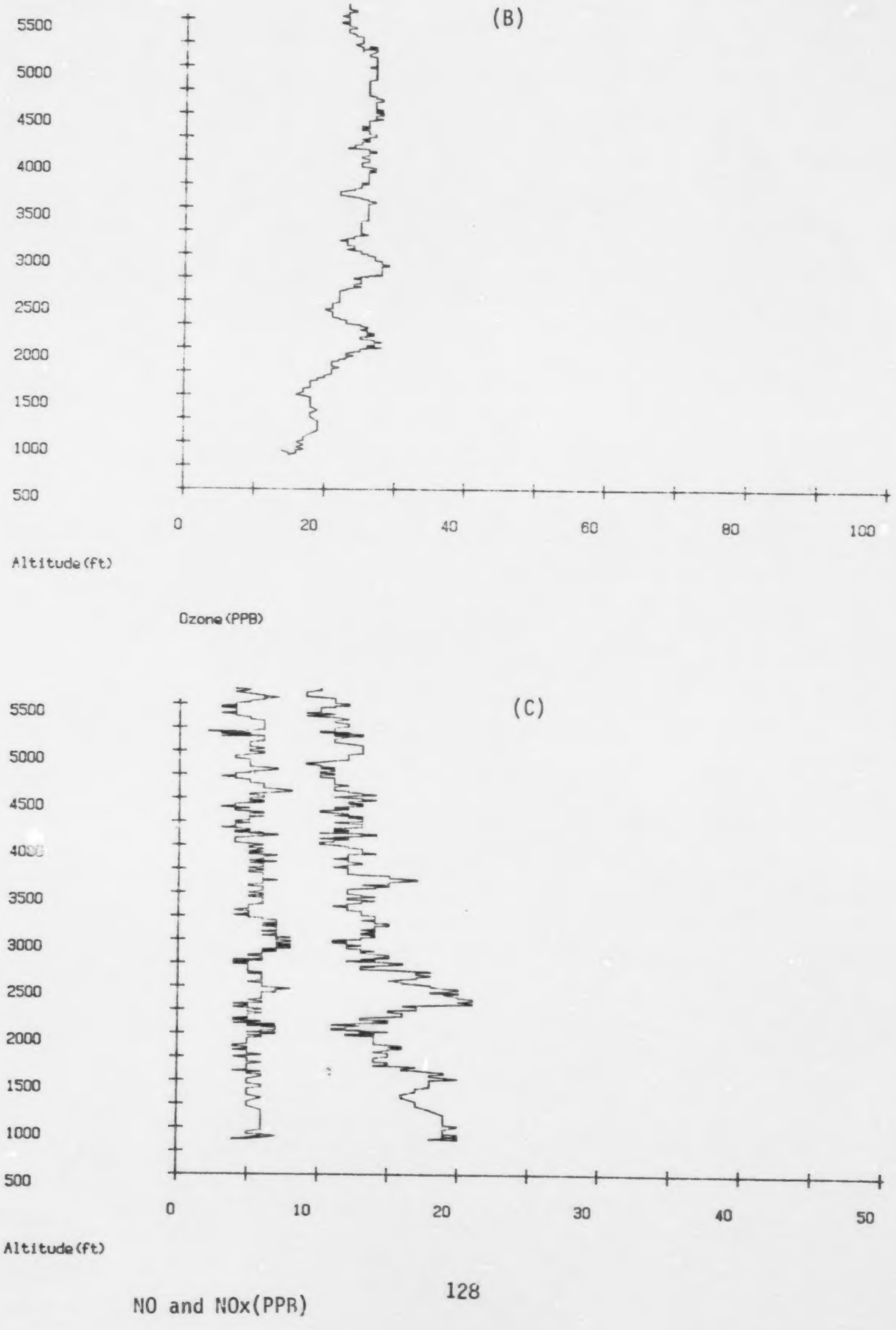


Figure C-6. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on August 16, 1985.

(Figure C-6, cont'd.)



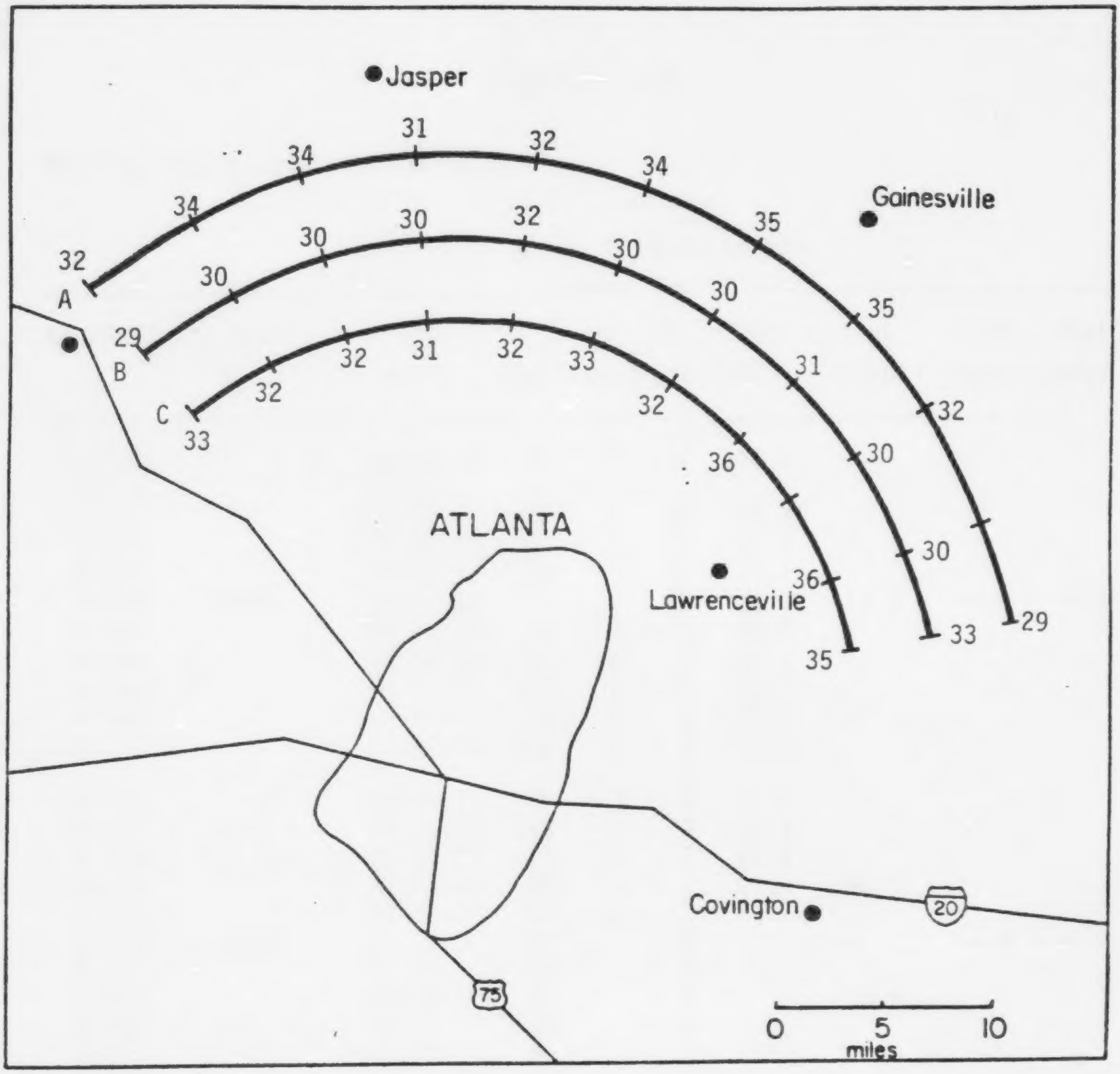

Jasper
Gainesville
ATLANTA
Lawrenceville
Covington
A
B
C
32
34
34
31
32
34
35
35
32
29
29
30
30
30
32
30
30
31
30
30
33
33
32
32
31
32
33
32
36
36
35
75
20
0
5
10
miles

Figure C-7. August 19 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude

A: 0435 - 0508 at 3000'
B: 0514 - 0541 at 4000'
C: 0547 - 0614 at 3000'

Wind: 020° at 12 knots

August 19, 1985

Morning Mixing Level: 1670 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/090		04:35:12	29	5	12	24.3			
A/078		04:38							
A/066		04:41:40	32	2	12	23.9			
A/054		04:45:00	35	5	11	23.9			
A/042		04:48:10	35	2	12	23.7			
A/030	3000'	04:51:30	34	4	12	23.9	17.0	<0.8	<0.3
A/018		04:54:30	32	4	9	24.4			
A/006		04:58:00	31	6	9	24.6			
A/354		05:01:11	34	2	10	24.7			
A/342		05:04:31	34	4	8	25.0			
A/330		05:07:41	32	3	9	21.8			
B/330		05:14:10	29	3	7	21.0			
B/342		05:16:50	30	1	7	21.1			
B/354		05:19:30	30	1	7	21.2			
B/006		05:22:10	30	3	7	21.5	40.8		
B/018		05:25:00	32	2	7	21.7			
B/030	4000'	05:28	30		6			<0.8	<0.3
B/042		05:30	30		8				
B/054		05:33	31		6		16.4		
B/066		05:36	30		5				
B/078		05:39	30		7				
B/090		05:41	33		7				
C/090		05:47	35		8				
C/078		05:50	36		8				
C/066		05:52			8				
C/054		05:55	36		8				
C/042		05:58	32		7				
C/030	3000'	06:00	33		7		19.6	<0.7	<0.3
C/018		06:03:00	32	2	8	22.5			
C/006		06:05:40	31	3	8	22.8			
C/354		06:08:20	32	2	8	23.0			
C/342		06:10:59	32	2	7	22.9			
C/330		06:13:39	33	1	5	22.9			

* See flight map for Arc; Radial off Atlanta City Center.

Table C-4. Hydrocarbon Concentrations (ppbC) in Samples Collected on August 19, 1985

Hydrocarbon	A/C Arc A 0449 - 0458 (EDT)	A/C Arc B 0517 - 0526 (EDT)	A/C Arc B 0529 - 0538 (EDT)	A/C Arc C 0556 - 0605 (EDT)
Ethane	4.3	4.4	4.9	5.1
Ethylene	(0.4)	(0.3)	(0.4)	(0.3)
Acetylene	0.4	0.2	0.3	0.4
Propane	2.4	1.8	2.4	1.8
Propene	0.4	-	0.2	0.2
i-Butane	0.6	0.3	0.6	0.7
n-Butane	1.6	1.2	1.4	1.7
i-Pentane	1.1	0.3	0.9	1.5
n-Pentane	0.6	0.2	0.5	1.2
Cyclopentane	0.3	0.3	0.5	0.5
Isoprene	1.2	*	1.6	1.6
2,3-Dimethylbutane	-	0.1	-	-
2-Methylpentane	0.3	0.2	0.3	0.4
3-Methylpentane	0.1	0.2	0.1	0.2
n-Hexane	0.3	0.4	0.3	0.4
Methylcyclopentane	0.2	0.2	-	0.2
Benzene	0.5	0.7	0.4	0.6
Cyclohexane	-	0.3	-	-
2-Methylhexane	-	0.4	-	-
3-Methylhexane	0.3	0.5	0.3	0.5
2,2,4-Trimethylpentane	-	0.2	-	-
Toluene	1.1	26.1	0.8	1.2
n-Octane	-	1.0	-	-
Ethylbenzene	0.4	0.4	-	0.1
p & *m*-Xylene	0.3	0.7	0.3	0.4
o-Xylene	0.2	0.4	0.2	0.6
Total Identified HC	17.0	40.8	16.4	19.6
TOTAL NMHC	17.7	50.6	16.4	23.0
% Paraffins	71	29	75	72
% Olefins	12	1	13	11
% Aromatics	15	69	10	15

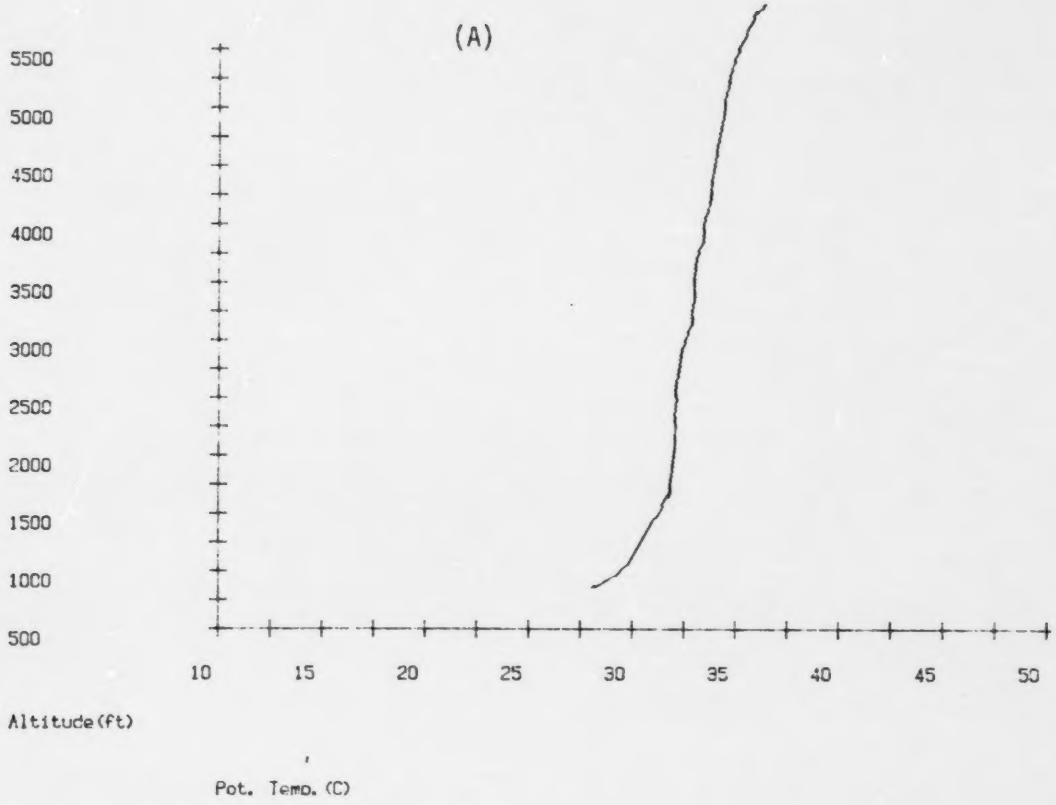
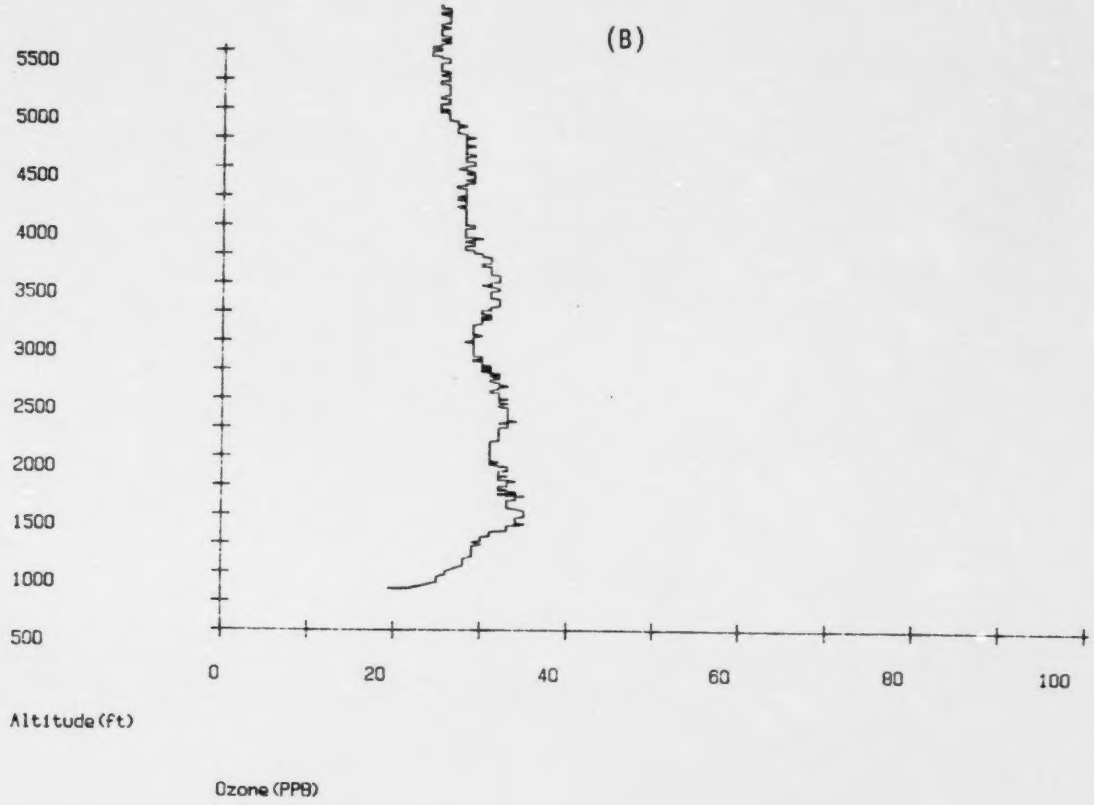
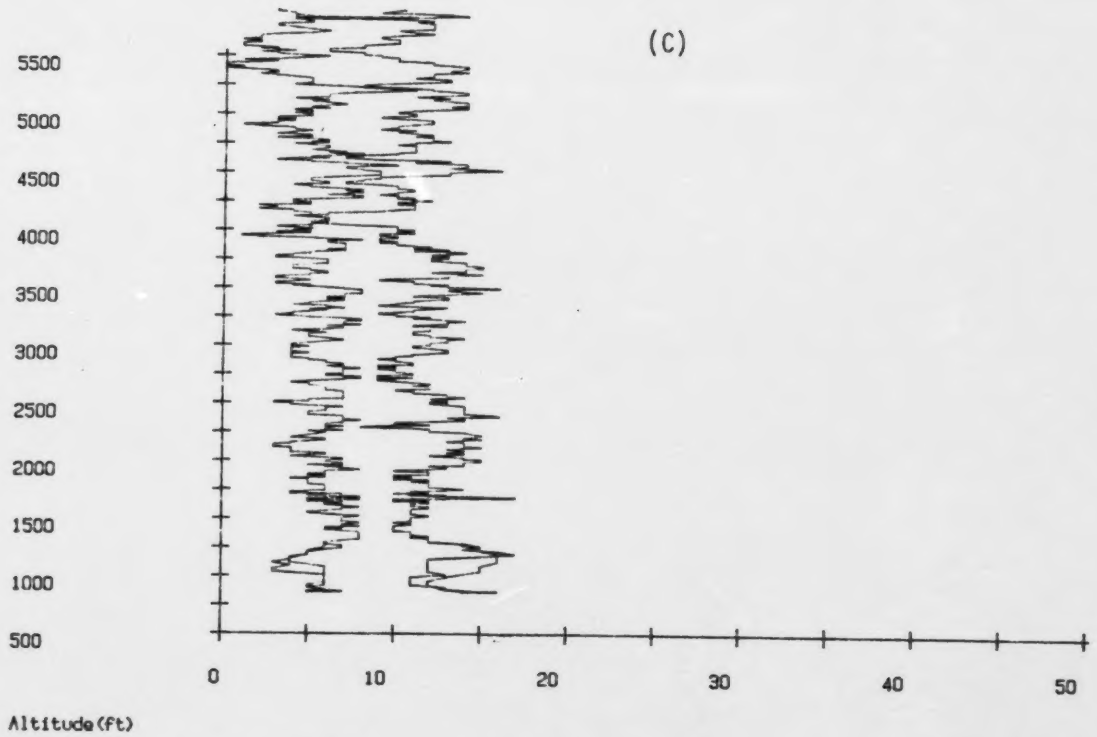
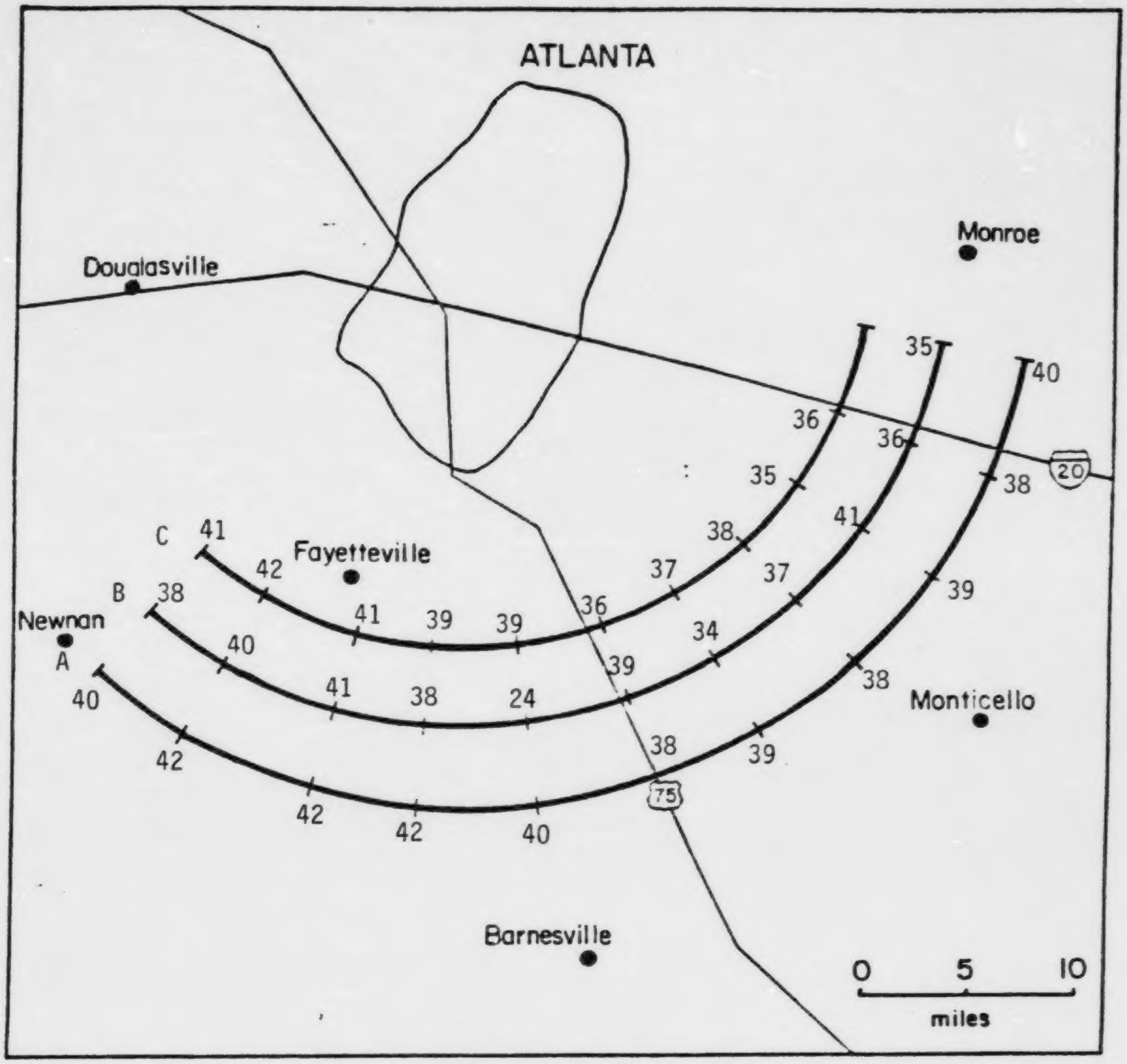


Figure C-8. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on August 19, 1985.

(Figure C-8. cont'd.)






ATLANTA
Monroe
Douglasville
Fayetteville
Newnan
Monticello
Barnesville
A
B
C
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0 5 10
miles
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38
40

Figure C-9. August 20 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude

A: 0444 - 0513 at 3000'
B: 0517 - 0545 at 4000'
C: 0554 - 0621 at 3000'

Wind: light and variable

August 20, 1985

Morning Mixing Level: 1750 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/100		04:44:02	40	4	8	25.2			
A/112		04:46:42	38	3	11	25.9			
A/124		04:49:32	39	4	11	25.1			
A/136		04:52:23	38	4	11	25.2			
A/148		04:55:13		3	9	25.2			
A/160	3000'	04:57:54	39	5	8	25.2	15.4		1.4
A/172		05:00:44	38	4	11	25.1			
A/184		05:03:34	40	4	10	25.0			
A/196		05:06:24	42	3	9	24.9			
A/208		05:09:14	42	3	11	25.6			
A/220		05:12:05	40	2	12	25.5			
B/220		05:17:34	38	4	12	21.8			
B/208		05:20:14	40	3	13	22.0			
B/196		05:22:55	41	3	12	22.1			
B/184		05:25:45	38	1	11	22.0	17.6		
B/172		05:28:26	24	3	11	22.1			
B/160	4000'	05:31	39		10			<0.7	<0.3
B/148		05:34	34		7				
B/136		05:37	37		9		61.6		
B/124		05:39	41		8				
B/112		05:42	36		6				
B/100		05:45	35		7				
C/100		05:51							
C/112		05:54:25	36	3	7	23.8			
C/124		05:57:15	35	2	7	23.7			
C/136		06:00:16	38	3	7	23.8			
C/148		05:03:06	37	2	9	23.7			
C/160	3000'	05:06:06	36	2	8	23.6	9.1	<0.7	<0.3
C/172		05:08:38	39	2	9	23.7			
C/184		05:12	39		7				
C/196		05:15	41		8				
C/208		05:18	42		9				
C/220		05:21	41		8				

* See flight map for Arc; Radial off Atlanta City Center.

Table C-5. Hydrocarbon Concentrations (ppbC) in Samples Collected on August 20, 1985

Hydrocarbon	A/C Arc A 0453 - 0502 (EDT)	A/C Arc B - 0535 (EDT)	A/C Arc C* 0543 - 0544 (EDT)	A/C Arc C* 0609 - 0610 (EDT)
Ethane	3.6	4.3	5.9	2.5
Ethylene	(0.3)	(0.3)	(0.5)	(0.3)
Acetylene	0.2	0.3	0.6	0.2
Propane	1.8	1.9	3.1	1.4
Propene	0.2	0.1	0.6	0.2
i-Butane	0.4	0.5	5.7	0.3
n-Butane	1.4	1.6	14.5	1.0
i-Pentane	1.0	1.5	13.0	0.6
n-Pentane	0.6	0.7	4.3	0.4
Cyclopentane	-	-	-	-
Isoprene	1.5	0.6	3.5	0.6
2,3-Dimethylbutane	0.1	0.1	-	-
2-Methylpentane	0.3	0.4	2.0	0.2
3-Methylpentane	0.1	0.2	1.1	0.1
n-Hexane	0.2	0.2	0.9	0.1
Methylcyclopentane	0.1	0.1	0.7	0.1
Benzene	0.6	0.8	1.2	0.4
Cyclohexane	-	-	-	-
2-Methylhexane	0.1	0.2	-	-
3-Methylhexane	0.1	-	-	-
2,2,4-Trimethylpentane	0.2	0.3	-	-
Toluene	0.9	1.0	2.7	0.6
n-Octane	-	0.2	-	-
Ethylbenzene	0.7	0.5	0.8	-
p & *m*-Xylene	0.3	1.2	0.3	0.1
o-Xylene	0.7	0.6	0.2	-
Total Identified HC	15.4	17.6	61.6	9.1
TOTAL NMHC	15.7	35.8	63.3	9.9
% Paraffins	65	69	84	74
% Olefins	13	6	7	12
% Aromatics	21	23	8	12

* no flow restrictor

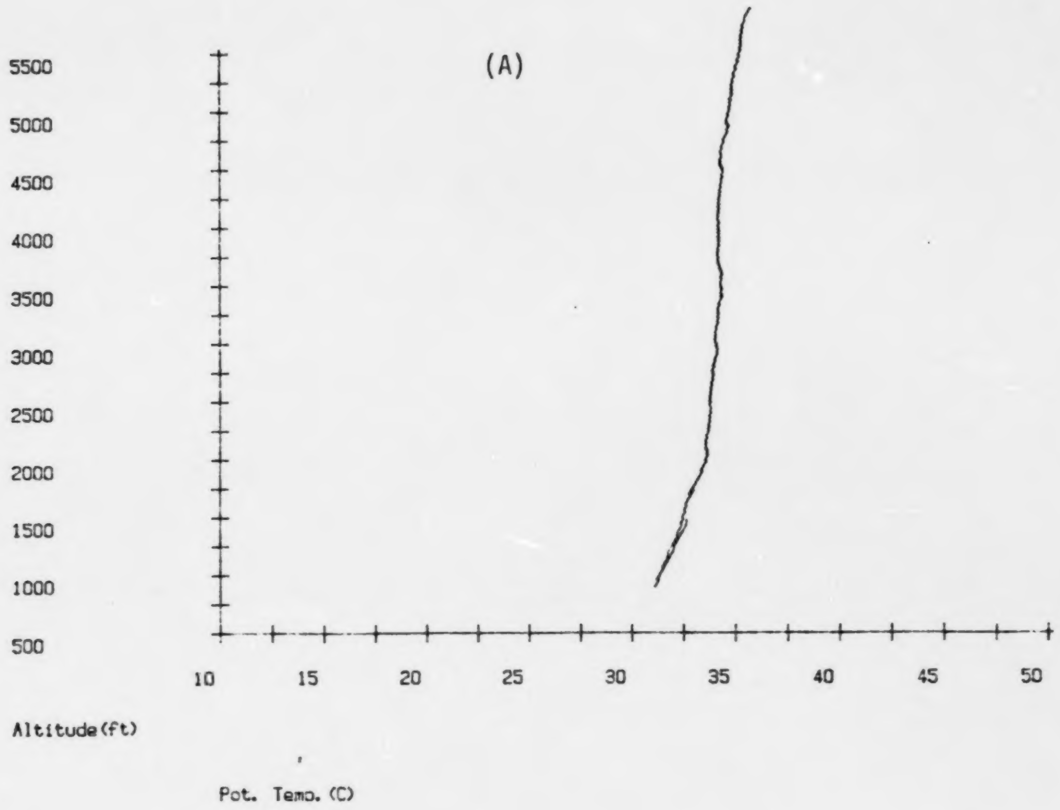
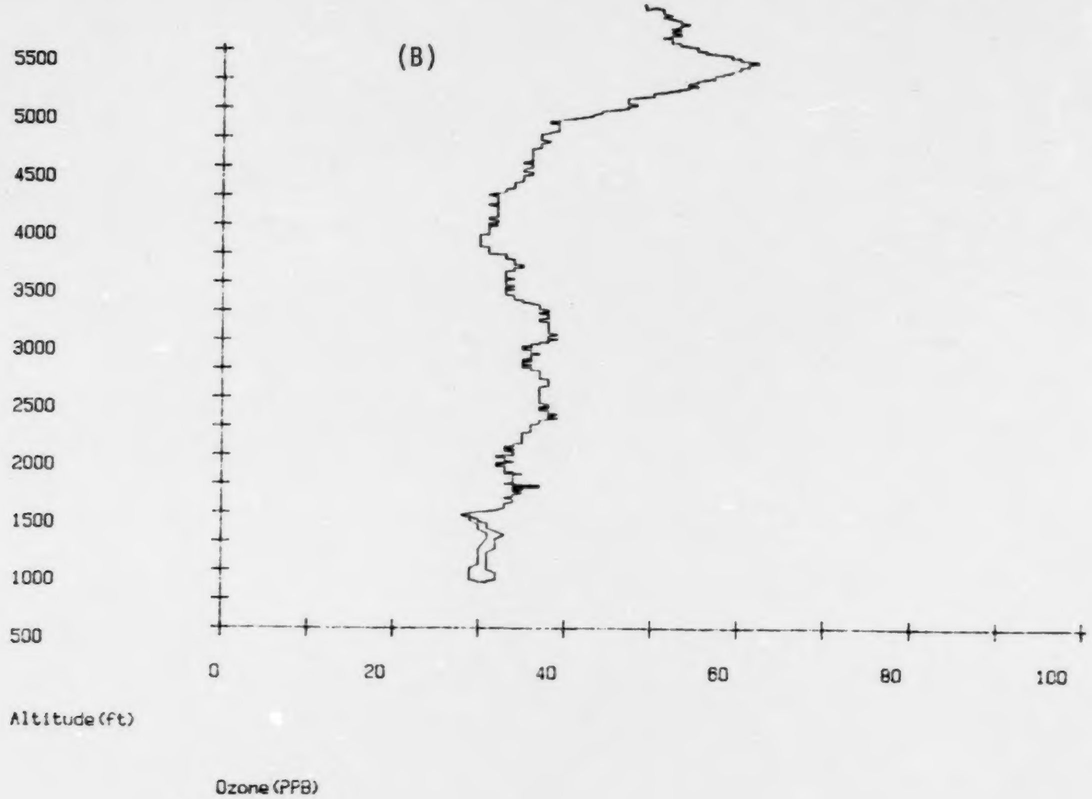
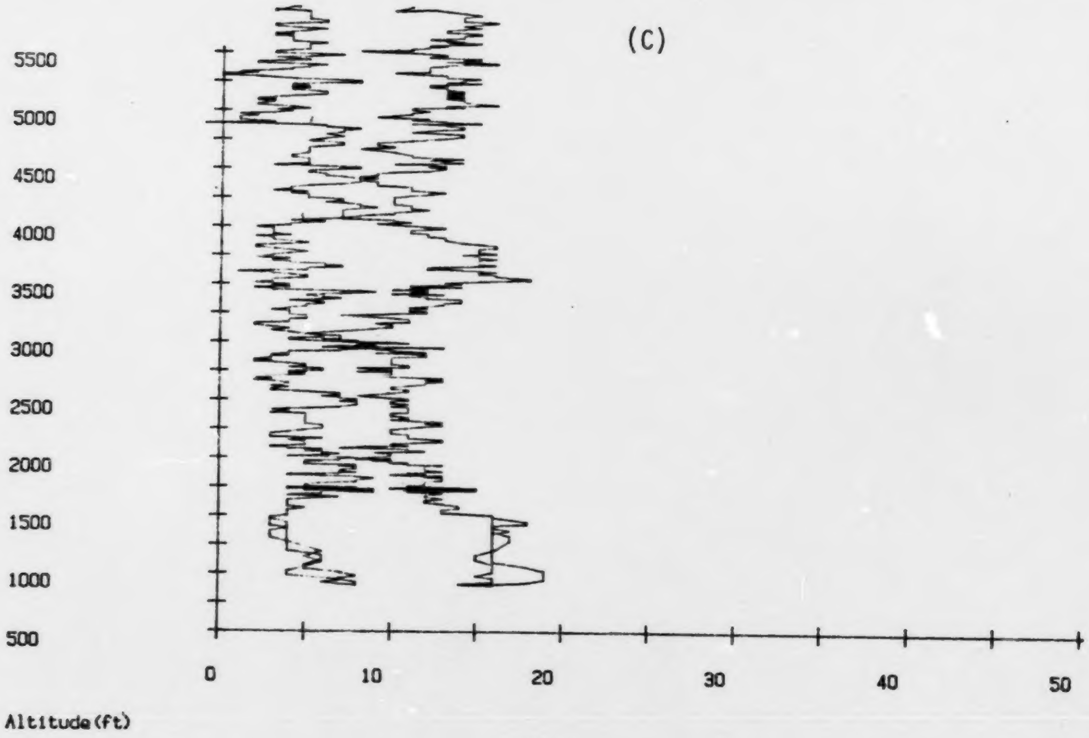


Figure C-10. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on August 20, 1985.

(Figure C-10. cont'd.)





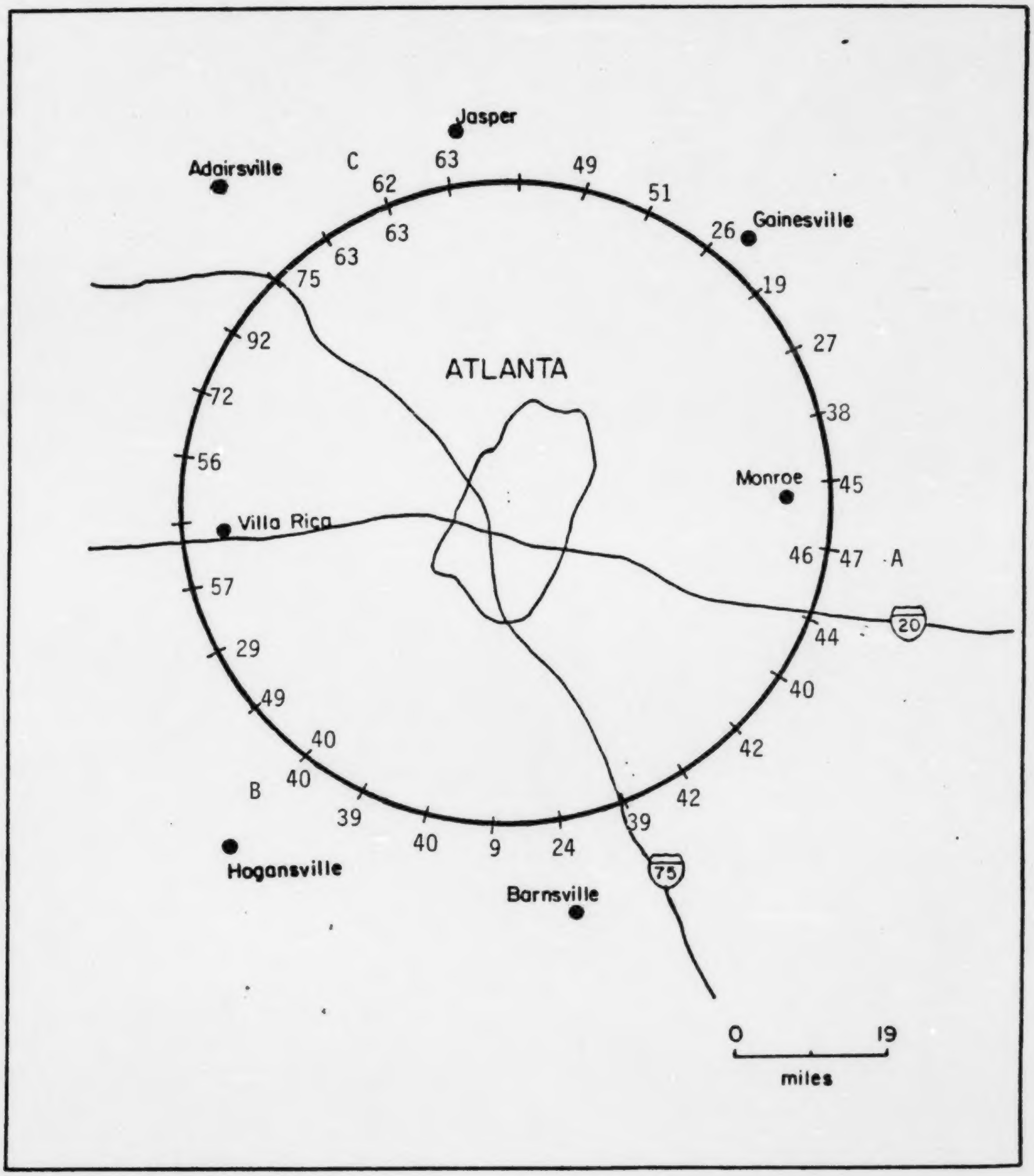

Jasper
Adairsville
C
63
62
49
51
26
Gainesville
63
63
75
19
27
92
ATLANTA
72
38
56
Monroe
45
Villa Rica
46
47
A
57
20
44
29
40
49
40
42
40
B
42
39
40
9
24
39
75
Hogansville
Barnsville
0
19
miles

Figure C-11. August 21 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude

A: 0437 - 0502 at 3000'
B: 0503 - 0535 at 3000'
C: 0536 - 0610 at 3000'

Wind: calm

August 21, 1985

Morning Mixing Level: 1600 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/100	3000'	04:37:08	47	1	11	25.2	11.8	<0.8	1.0
A/112		04:39:29	44	3	12	25.4			
A/124		04:41:58	40	2	10	25.3			
A/136		04:44:19	42	3	11	25.6			
A/148		04:46:48	42	4	11	25.5			
A/160		04:49:18	39	3	12	25.9			
A/172		04:51:39	24	3	17	25.8			
A/184		04:54:09	9	4	41	25.8			
A/196		04:56:38	40	4	10	25.6			
A/208		04:59:08	39	2	9	25.5			
A/220		05:02	40		10				
B/220	3000'	05:04	40		9		20.0	4.1	<0.3
B/232		05:07:00	49	3	11	24.8			
B/244		05:10:00	29	3	24	24.2			
B/256		05:13:10	57	2	11	24.3			
B/268		05:16:20		4	12	24.3			
B/280		05:19:30	56	5	11	24.0			
B/292		05:22:30	72	4	13	24.1			
B/304		05:25:41	92	4	14	24.1			
B/316		05:28:52	75	4	12	24.1			
B/328		05:31:52	63	2	13	23.9			
B/340		05:35:02	63	3	11	24.0			
C/340	3000'	05:37:49	62	2	10	24.0	17.3	<0.6	<0.3
C/352		05:40:49	63	1	10	24.0			
C/004		05:43:59		3	13	24.2			
C/016		05:47:19	49	2	9	22.7			
C/028		05:50:31	51	3	8	22.4			
C/040		05:53:40	26	1	23	24.0			
C/052		05:56:51	19	4	36	24.5			
C/064		06:00:11	27	4	24	24.4			
C/076		06:03:22	38	3	14	24.0			
C/088		06:06:33	45	3	11	24.5			
C/100		06:09:43	46	3	10	25.3			

* See flight map for Arc; Radial off Atlanta City Center.

Table C-6. Hydrocarbon Concentrations (ppbC) in Samples Collected on August 21, 1985

Hydrocarbon	A/C Arc A 0446 - 0454 (EDT)	A/C Arc B 0514 - 0522 (EDT)	A/C Arc C 0542 - 0550 (EDT)	A/C Arc C 0555 - 0603 (EDT)
Ethane	3.4	4.1	3.9	3.6
Ethylene	(0.3)	(0.6)	(0.5)	(0.5)
Acetylene	0.3	0.5	0.4	0.5
Propane	1.8	3.3	3.0	2.7
Propene	0.1	0.4	-	0.4
i-Butane	0.4	0.8	0.7	0.8
n-Butane	1.0	2.1	2.2	2.4
i-Pentane	0.8	1.5	1.4	1.9
n-Pentane	0.4	0.7	0.9	*
Cyclopentane	-	-	-	*
Isoprene	0.5	0.6	0.2	*
2,3-Dimethylbutane	-	-	0.1	*
2-Methylpentane	0.3	0.4	0.5	*
3-Methylpentane	0.1	0.2	0.3	*
n-Hexane	0.2	0.4	0.5	*
Methylcyclopentane	0.1	0.1	0.1	*
Benzene	0.5	0.9	0.7	*
Cyclohexane	-	-	-	*
2-Methylhexane	-	-	0.2	*
3-Methylhexane	0.2	0.6	0.1	*
2,2,4-Trimethylpentane	-	-	0.2	*
Toluene	0.8	1.2	0.9	*
n-Octane	-	-	0.1	*
Ethylbenzene	0.1	0.3	0.1	*
p & *m*-Xylene	0.2	0.4	0.1	*
o-Xylene	0.3	0.9	0.1	*
Total Identified HC	11.8	20.0	17.3	*
TOTAL NMHC	11.8	22.3	17.3	*
% Paraffins	73	72	82	*
% Olefins	8	8	4	*
% Aromatics	16	18	12	*

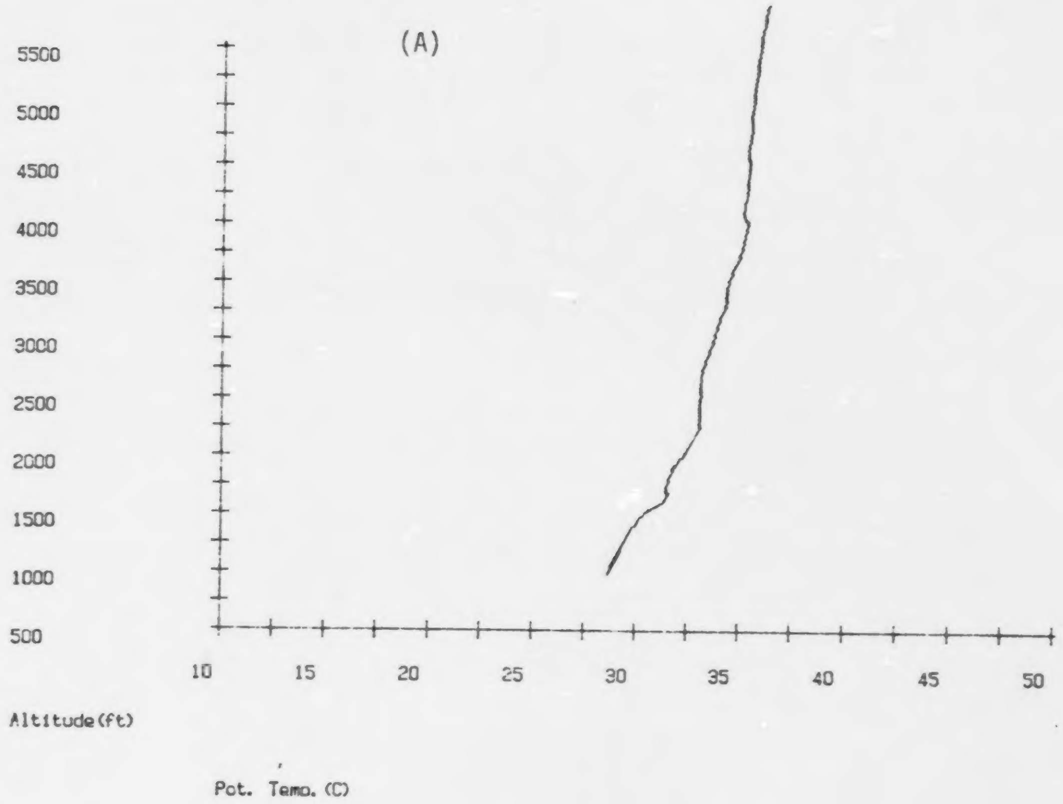
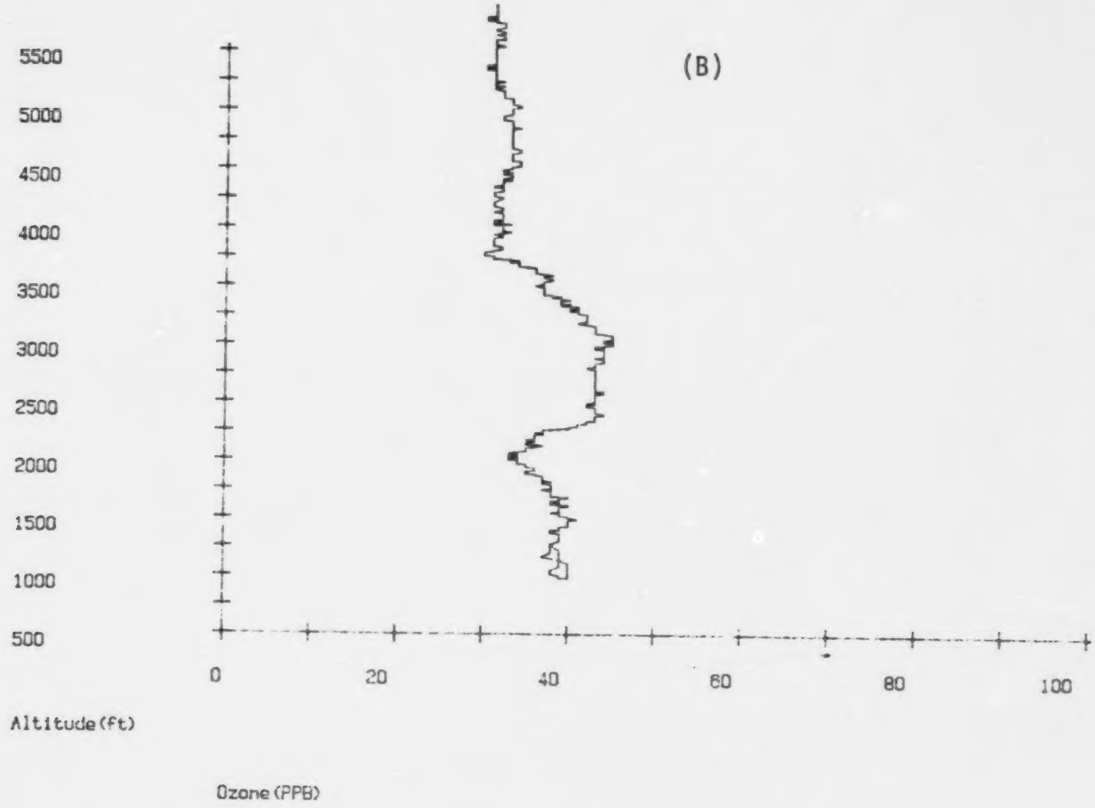
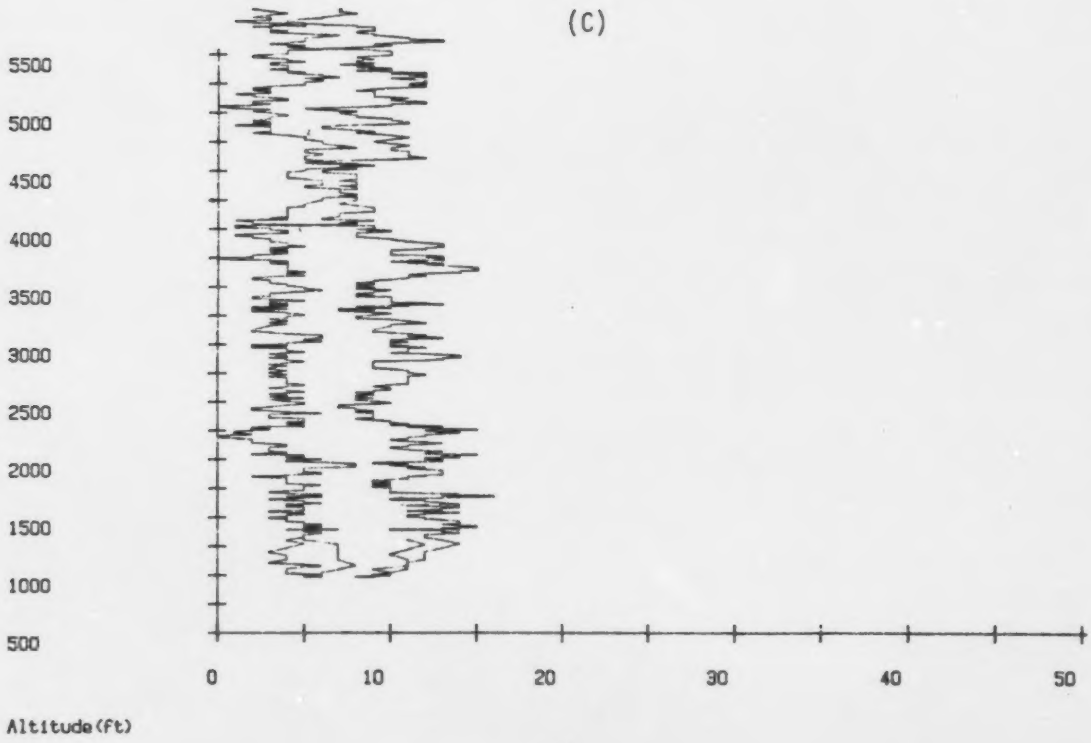
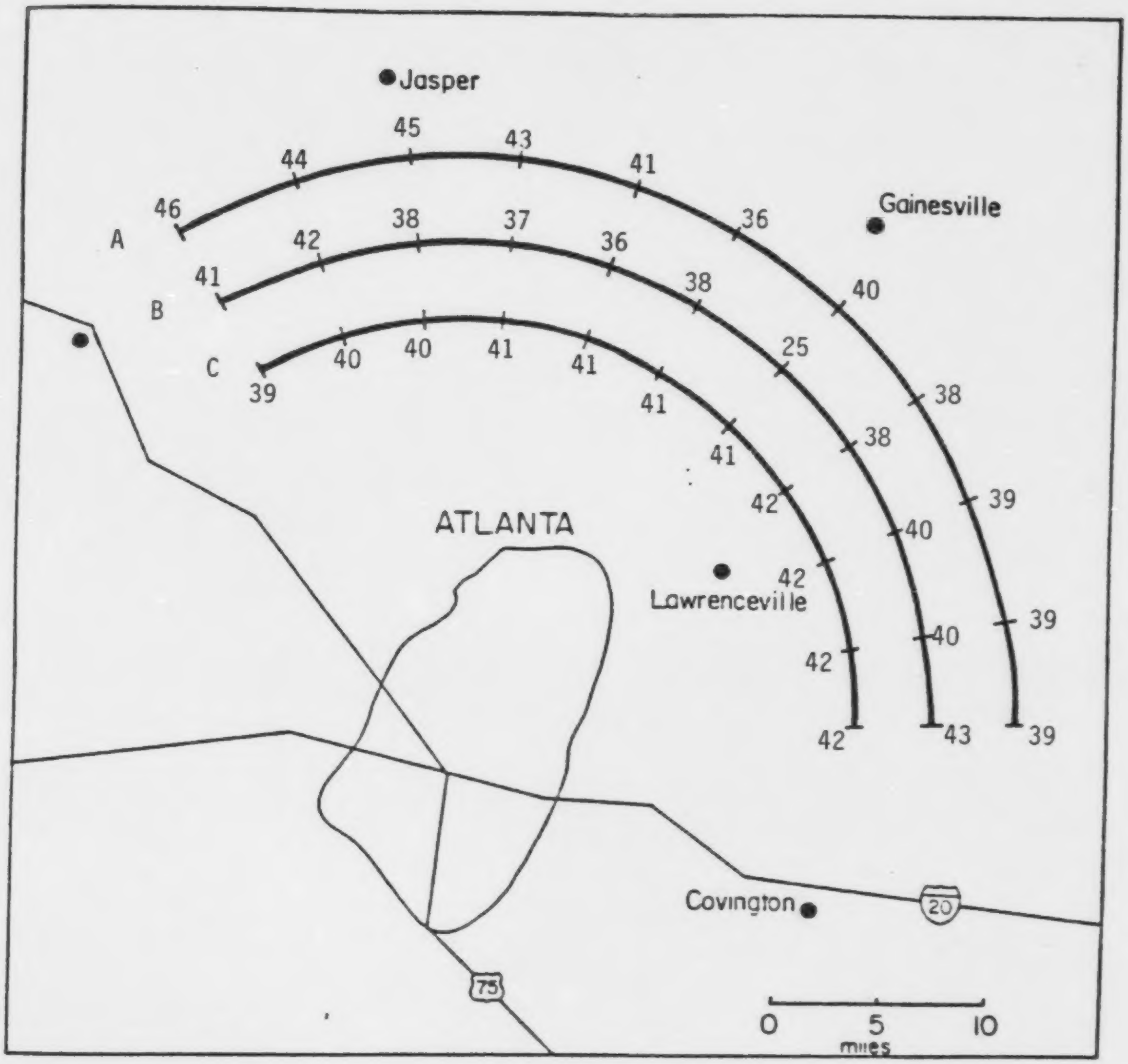


Figure C-12. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on August 21, 1985.

(Figure C-12. cont'd.)






Jasper
A
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45
43
41
36
Gainesville
B
41
42
38
37
36
38
40
C
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40
41
41
41
25
38
41
38
42
39
42
40
ATLANTA
Lawrenceville
42
40
39
42
42
43
39
Covington
20
75
0
5
10
miles

Figure C-13. August 22 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude

A: 0441 - 0508 at 3500'
B: 0512 - 0541 at 4000'
C: 0544 - 0610 at 3500'

Wind: 020° at 12 knots

August 22, 1985

Morning Mixing Level: 1400 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/080	3500'	04:41:32	39	3	9	21.9	30.8		<0.8
A/068		04:44:02	39	3	8	21.8			
A/056		04:46:42	39	2	11	21.4			
A/044		04:49:12	38	3	8	21.1			
A/032		04:51:52	40	2	9	21.0			
A/020		04:54:32	36	3	9	20.8			
A/008		04:57:12	41	4	10	20.8			
A/356		04:59:42	43	1	8	21.0			
A/344		05:02:22	45	3	11	20.8			
A/332		05:05:02	44	4	9	20.9			
A/320		05:07:32	46	2	9	21.2			
B/320	4000'	05:12:56	41	2	8	21.6	27.8		1.5
B/332		05:15:37	42	1	10	20.9			
B/344		05:18:27	38	1	12	19.2			
B/356		05:21:07	37	3	9	19.2			
B/008		05:23:57	36	2	12	19.1			
B/020		05:26:37	38	3	10	19.0			
B/032		05:29:27	25	3	9	19.6			
B/044		05:32:07	38	2	10	19.6			
B/056		05:34:57	40	3	7	20.0			
B/068		05:37:37	40	2	7	20.3			
B/080		05:40:17	43	2	8	20.3			
C/080	3500'	05:44:58	42	2	9	21.3	29.6	<0.8	<0.3
C/068		05:47:18	42	4	7	21.1			
C/056		05:49:48	42	3	7	20.9			
C/044		05:52:08	42	1	9	20.7			
C/032		05:54:38	41	3	8	20.5			
C/020		05:57:08	41	3	9	20.3			
C/008		05:59:29	41	2	10	20.1			
C/356		06:02	41		8				
C/344		06:04	40		9				
C/332		06:06:49	40	4	6	19.6			
C/320		06:09:19	39	3	9	19.6			

* See flight map for Arc; Radial off Atlanta City Center.

Table C-7. Hydrocarbon Concentrations (ppbC) in Samples Collected on August 22, 1985

Hydrocarbon	A/C Arc A 0516 - 0524 (EDT)	A/C Arc B 0527 - 0535 (EDT)	A/C Arc C 0554 - 0602 (EDT)
Ethane	7.2	9.2	10.1
Ethylene	(0.8)	(1.0)	(1.0)
Acetylene	0.4	0.4	0.7
Propane	4.7	5.4	5.4
Propene	0.4	0.2	0.3
i-Butane	1.4	1.0	1.1
n-Butane	4.0	2.8	2.9
i-Pentane	2.6	1.6	2.1
n-Pentane	1.6	0.8	1.9
Cyclopentane	-	-	0.2
Isoprene	0.4	0.3	0.1
2,3-Dimethylbutane	0.3	0.1	-
2-Methylpentane	0.8	0.4	0.4
3-Methylpentane	0.5	0.3	0.2
n-Hexane	0.7	-	0.3
Methylcyclopentane	0.3	0.2	0.1
Benzene	0.8	0.7	0.7
Cyclohexane	-	0.7	-
2-Methylhexane	0.6	0.3	0.1
3-Methylhexane	0.3	0.2	0.3
2,2,4-Trimethylpentane	0.5	0.3	-
Toluene	1.4	1.3	1.2
n-Octane	-	-	-
Ethylbenzene	0.3	0.2	-
p & *m*-Xylene	0.4	0.3	0.2
o-Xylene	0.4	0.1	0.3
Total Identified HC	30.8	27.8	29.6
TOTAL NMHC	32.5	27.8	29.6
% Paraffins	83	86	85
% Olefins	5	5	5
% Aromatics	11	9	8

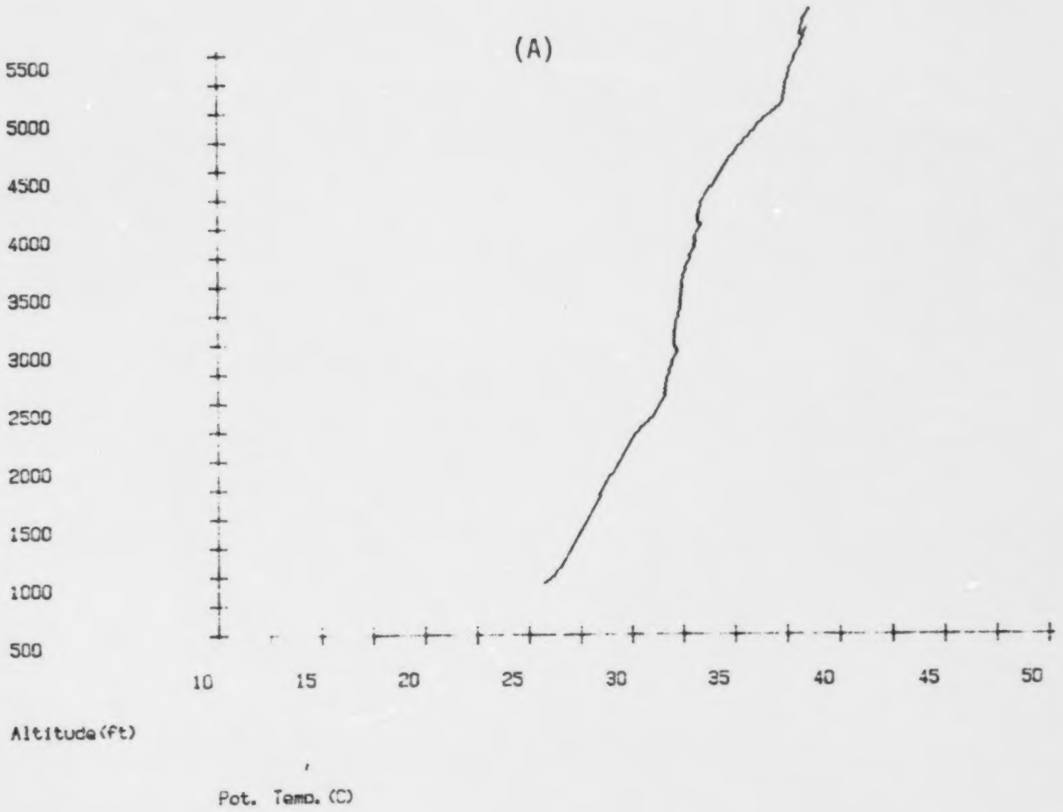
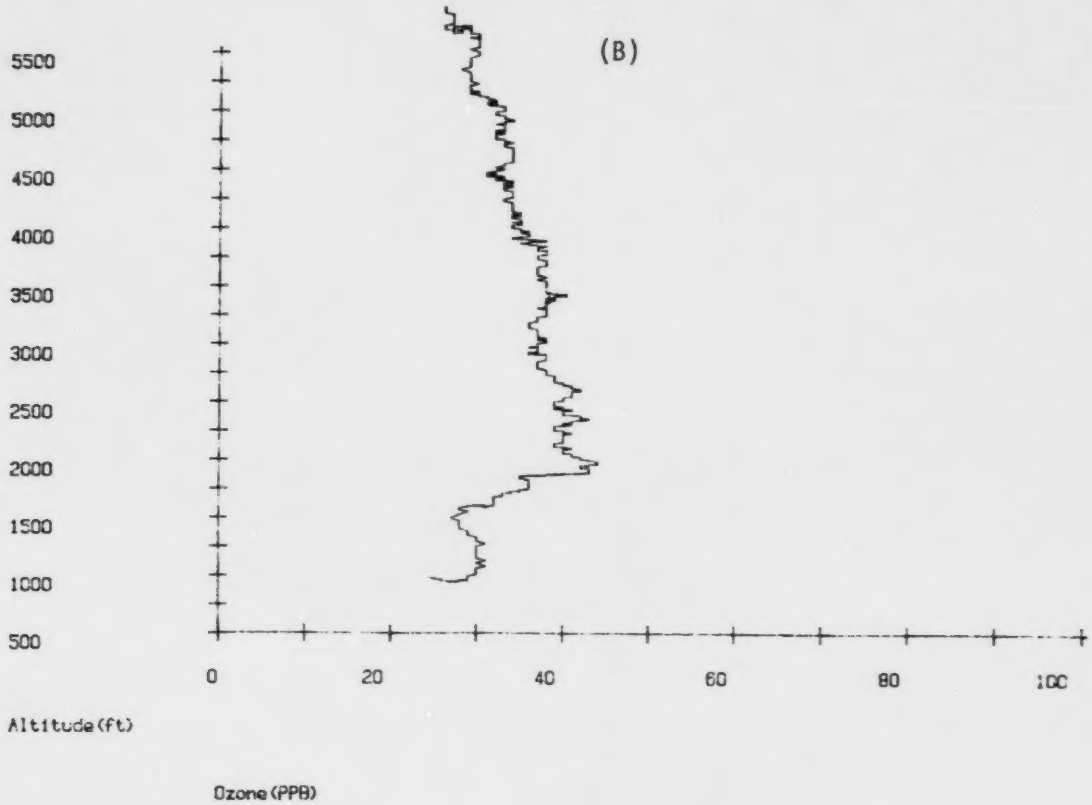
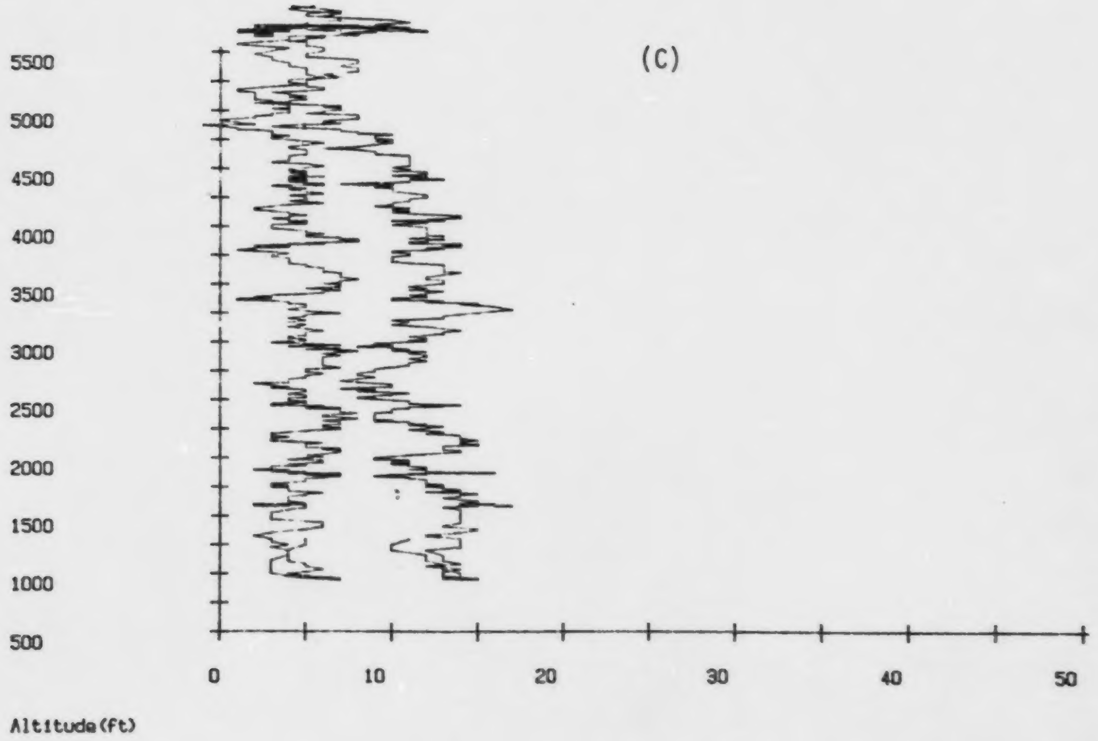
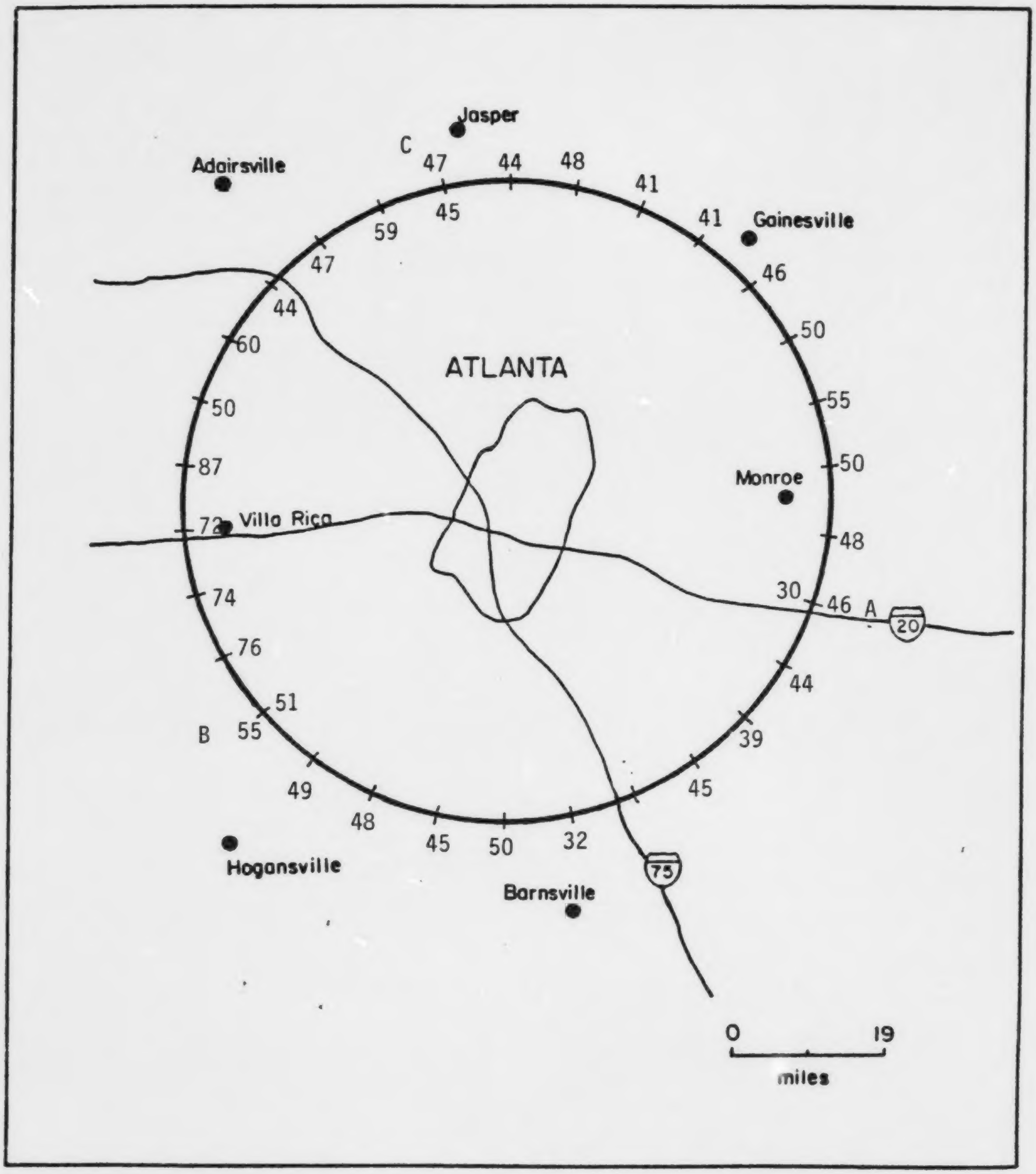


Figure C-14. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on August 22, 1985.

(Figure C-14. cont'd.)






Jasper
Adairsville
Gainesville
ATLANTA
Monroe
Villa Rica
Hogansville
Barnsville
C
47
44
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87
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72
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74
30
46
A
20
76
44
51
B
55
39
49
48
45
50
32
45
75
0
19
miles

Figure C-15. August 23 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude

A: 0439 - 0510 at 4000'
B: 0511 - 0538 at 4000'
C: 0539 - 0609 at 4000'

Wind: light and variable

August 23, 1985

Morning Mixing Level: 1500 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/110	4000'	04:39:37	46	2	10	20.1	20.6	<0.9	<0.4
A/122		04:42:27	44	2	10	20.3			
A/134		04:45:27	39	3	14	20.3			
A/146		04:48:27	45	1	12	20.6			
A/158		04:51:27	-	2	9	20.9			
A/170		04:54:27	32	6	16	21.0			
A/182		04:57:28	50	2	9	21.4			
A/194		05:00:28	45	5	8	21.5			
A/206		05:03:28	48	2	9	21.5			
A/218		05:06:28	49	3	8	21.7			
A/230		05:09:18	55	3	8	21.7			
B/230	4000'	05:12:20	51	4	9	21.6	39.4		<0.3
B/242		05:14:50	76	1	12	21.0			
B/254		05:17:30	74	2	14	21.0			
B/266		05:20:10	72	4	14	20.6			
B/278		05:22:50	87	1	16	20.8			
B/290		05:25:20	50	1	11	20.4			
B/302		05:28:00	60	3	12	20.3			
B/314		05:30:40	44	3	9	20.0			
B/326		05:33:10	47	0	8	20.0			
B/338		05:35:50	59	1	13	20.4			
B/350		05:37:30	45	3	12	19.7			
C/350	4000'	05:41:11	47	1	12	19.6	45.3	1.2	<0.3
C/002		05:44:02	44	2	11	19.2			
C/014		05:46:51	48	3	11	19.4			
C/026		05:49:41	41	0	19	19.2			
C/038		05:52:31	41	2	19	18.4			
C/050		05:55	46		11				
C/062		05:58	50		9				
C/074		06:01	55		8				
C/086		06:04	50		9				
C/098		06:06	48		8				
C/110		06:09	30		15				

* See flight map for Arc; Radial off Atlanta City Center.

Table C-8. Hydrocarbon Concentrations (ppbC) in Samples Collected on August 23, 1985

Hydrocarbon	A/C Arc A 0450 - 0458 (EDT)	A/C Arc B 0522 - 0530 (EDT)	A/C Arc C 0545 - 0553 (EDT)	A/C Arc C 0556 - 0604 (EDT)
Ethane	6.6	8.6	8.3	8.3
Ethylene	(0.6)	(0.9)	(0.9)	(0.8)
Acetylene	0.4	1.3	0.8	0.5
Propane	3.6	5.0	4.8	4.5
Propene	0.4	-	-	0.2
i-Butane	0.7	1.7	1.2	1.2
n-Butane	2.2	5.4	3.9	5.1
i-Pentane	1.2	4.0	2.3	2.9
n-Pentane	0.6	1.7	1.2	1.4
Cyclopentane	0.7	0.4	*	0.6
Isoprene	-	0.3	*	0.1
2,3-Dimethylbutane	-	0.3	*	0.2
2-Methylpentane	0.4	0.8	*	0.9
3-Methylpentane	0.2	0.5	*	0.5
n-Hexane	0.2	0.6	*	0.3
Methylcyclopentane	0.1	0.4	*	0.5
Benzene	0.7	1.2	*	1.2
Cyclohexane	-	0.1	*	0.6
2-Methylhexane	-	0.6	*	0.6
3-Methylhexane	0.2	0.4	*	0.8
2,2,4-Trimethylpentane	-	0.7	*	-
Toluene	1.1	2.5	*	5.6
n-Octane	-	0.4	*	0.6
Ethylbenzene	0.1	0.6	*	3.4
p & *m*-Xylene	0.2	0.6	*	3.2
o-Xylene	0.4	0.4	*	1.3
Total Identified HC	20.6	39.4	*	45.3
TOTAL NMHC	22.9	40.9	*	61.3
% Paraffins	81	80	*	65
% Olefins	5	3	*	2
% Aromatics	12	14	*	32

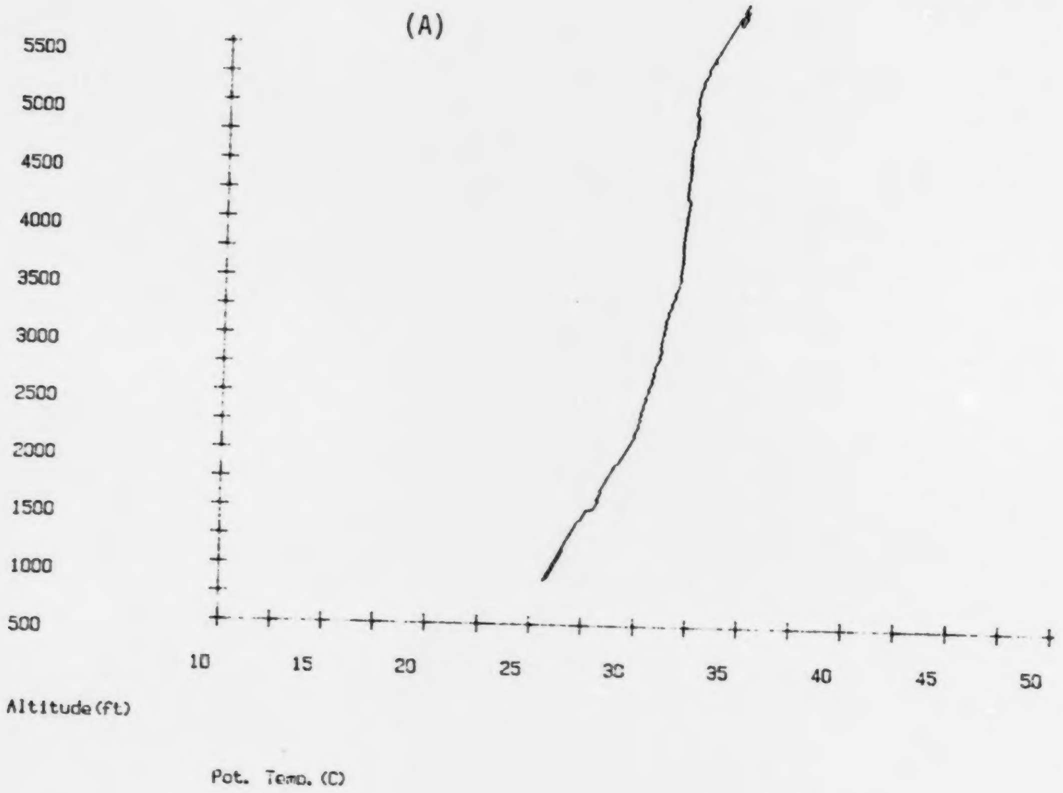
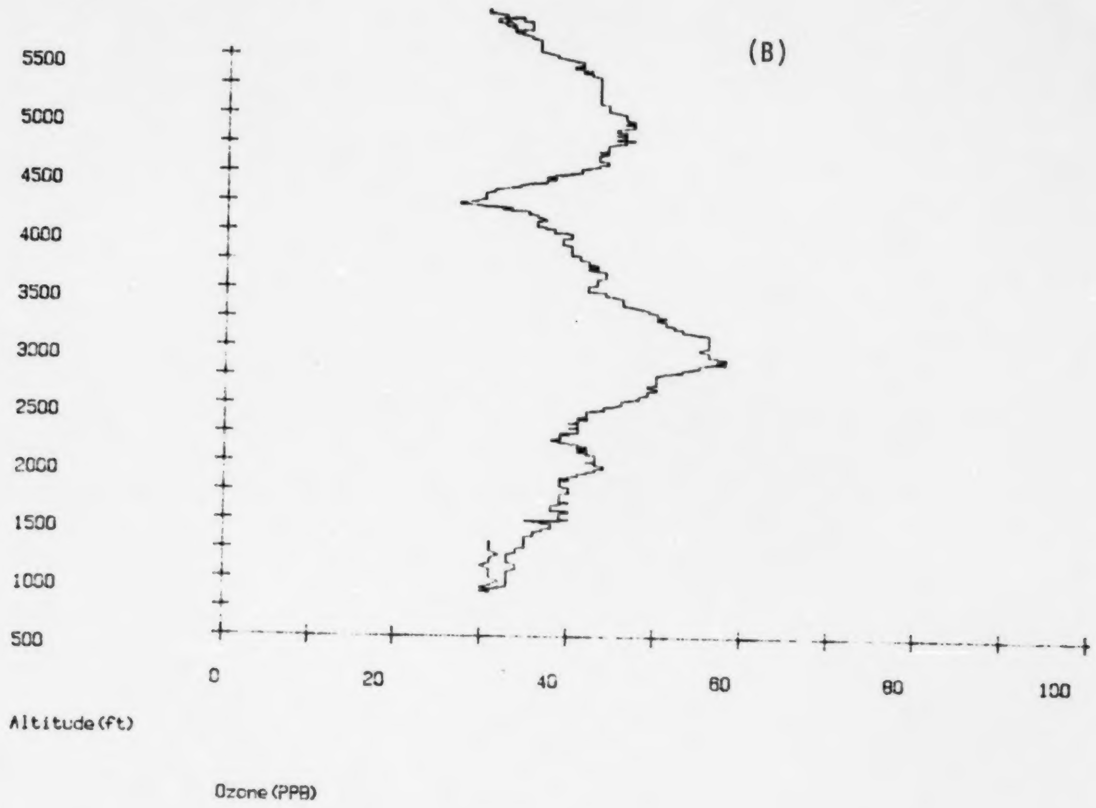
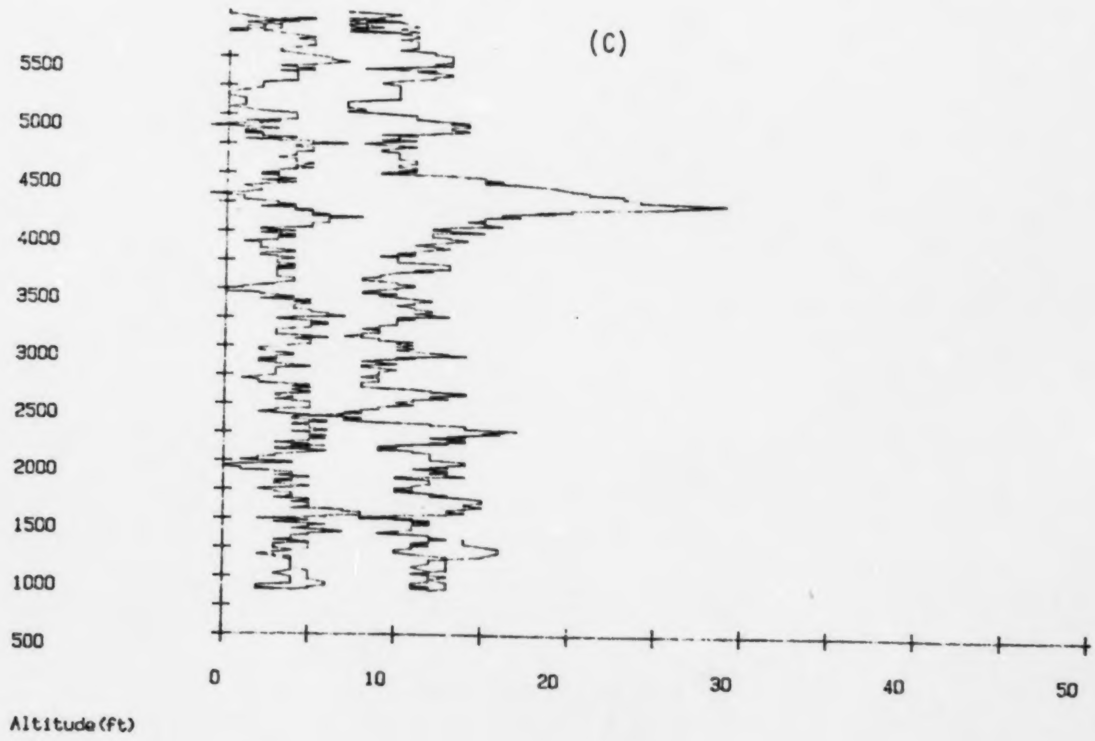


Figure C-16. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on August 23, 1985.

(Figure C-16. cont'd.)





APPENDIX D

Aircraft Flight Maps and Pollutant Measurement Data Obtained from Birmingham, Alabama

BIRMINGHAM AIR QUALITY DATA

This section provides a tabulation of airborne data collected in the Birmingham area during the period August 26-29, 1985. For each sampling day, there is a flight map with ozone concentrations marked along the route, a tabulation of air quality data, a listing of individual hydrocarbon concentrations and a graphical summary of ozone, NO_x and temperature changes with altitude.

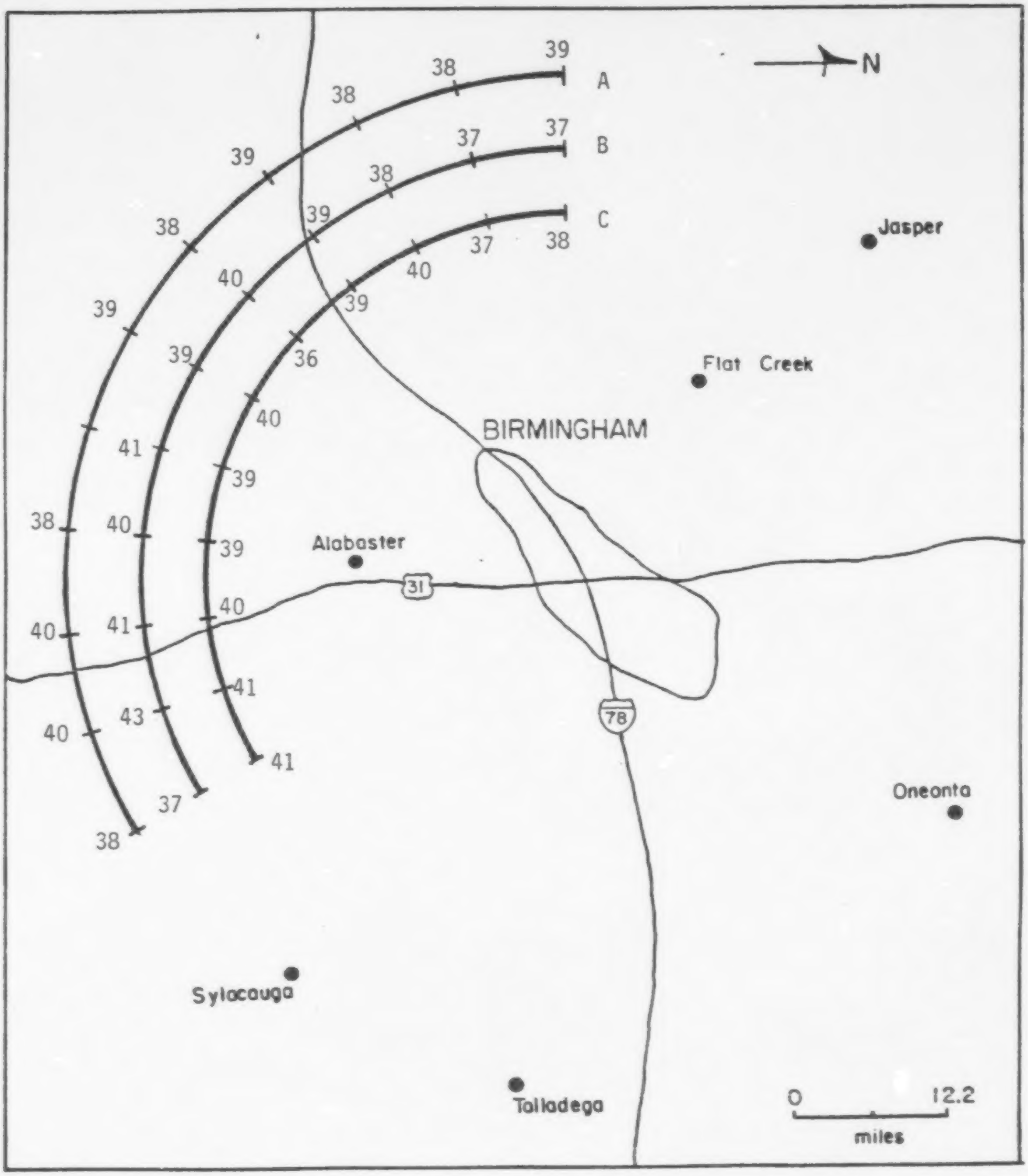
NOTES on Hydrocarbon Tables

* Means data not available

- Means concentration less than 0.1 ppbC

( ) Ethylene values in parentheses were calculated by multiplying the propane concentration by 0.18. This was necessary in cases of obvious ethylene contamination due to the presence of a chemiluminescent ozone analyzer. The ethylene-propane ratio was derived from airborne samples that were free of contamination problems.

TNMHC is the sum of all gas chromatographic peaks


N
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38
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43
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38
37
40
39
36
40
39
39
40
41
41
Jasper
Flat Creek
BIRMINGHAM
Alabaster
31
78
Oneonta
Sylacauga
Talladega
0
12.2
miles

Figure D-1. August 26 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude

A: 0440 - 0508 at 3000'
B: 0513 - 0542 at 4000'
C: 0549 - 0614 at 3000'

Wind: 210° at 12 knots

August 26, 1985

Morning Mixing Level: 1100 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/150	3000'	04:40:08	38	1	9	23.2	19.1	<1.1	<0.5
A/162		04:42:48	40	2	10	23.6			
A/174		04:45:38	40	1	8	22.9			
A/186		04:48:18	38	2	9	22.7			
A/198		04:51:07		1	10	22.5			
A/210		04:53:57	39	3	10	21.6			
A/222		04:56:37	38	2	10	21.6			
A/234		04:59:27	39	0	10	21.7			
A/246		05:02	38		8				
A/258		05:05:00	38	0	9	21.4			
A/270		05:07:31	39	3	10	21.5			
B/270	4000'	05:13:55	37	1	8	18.3	26.6	<0.7	<0.3
B/258		05:16:36	37	2	9	18.5			
B/246		05:19:26	38	2	10	18.6			
B/234		05:22.06	39	2	6	18.9			
B/222		05:24:56	40	1	8	19.2			
B/210		05:27:36	39	0	8	19.6			
B/198		05:30:26	41	1	8	19.9			
B/186		05:33:16	40	0	8	20.1			
B/174		05:35:57	41	1	7	20.0			
B/162		05:38:37	43	2	8	20.5			
B/150		05:41:11	37	2	8	21.0			
C/150	3000'	05:45					21.2		<0.3
C/162		05:48:56	41	1	9	22.2			
C/174		05:51:36	40	1	8	22.0			
C/186		05:54:16	39	2	10	21.7			
C/198		05:57:06	39	0	9	21.5			
C/210		05:59:46	40	2	8	21.4			
C/222		06:02:26	36	2	9	20.9			
C/234		06:05:16	39	1	10	21.5			
C/246		06:07:57	40	1	9	21.4			
C/258		06:10:47	37	2	10	20.5			
C/270		06:13:17	38	2	7	20.0			

* See flight map for Arc; Radial off Birmingham City Center.

Table D-1. Hydrocarbon Concentrations (ppbC) in Samples Collected on August 26, 1985

Hydrocarbon	A/C Arc A 0450 - 0458 (EDT)	A/C Arc B 0524 - 0532 (EDT)	A/C Arc C 0556 - 0604 (EDT)
Ethane	5.5	8.5	5.4
Ethylene	(0.7)	(1.1)	(0.7)
Acetylene	0.2	0.2	0.2
Propane	4.1	6.3	4.1
Propene	-	0.2	0.2
i-Butane	1.9	2.5	2.2
n-Butane	2.1	2.7	2.0
i-Pentane	0.8	1.1	1.0
n-Pentane	0.6	0.7	1.3
Cyclopentane	0.3	0.3	0.3
Isoprene	0.3	0.3	0.2
2,3-Dimethylbutane	-	-	-
2-Methylpentane	0.3	0.3	0.3
3-Methylpentane	0.1	0.2	0.2
n-Hexane	0.3	0.3	0.3
Methylcyclopentane	0.1	0.2	0.1
Benzene	0.4	0.6	0.4
Cyclohexane	-	-	0.4
2-Methylhexane	-	-	0.2
3-Methylhexane	-	-	0.1
2,2,4-Trimethylpentane	-	-	0.3
Toluene	0.7	0.6	0.7
n-Octane	-	-	-
Ethylbenzene	0.1	-	0.2
p & *m*-Xylene	0.2	0.2	0.3
o-Xylene	0.4	0.3	0.1
Total Identified HC	19.1	26.6	21.2
TOTAL NMHC	21.3	26.7	25.3
% Paraffins	85	87	86
% Olefins	5	6	5
% Aromatics	9	6	8

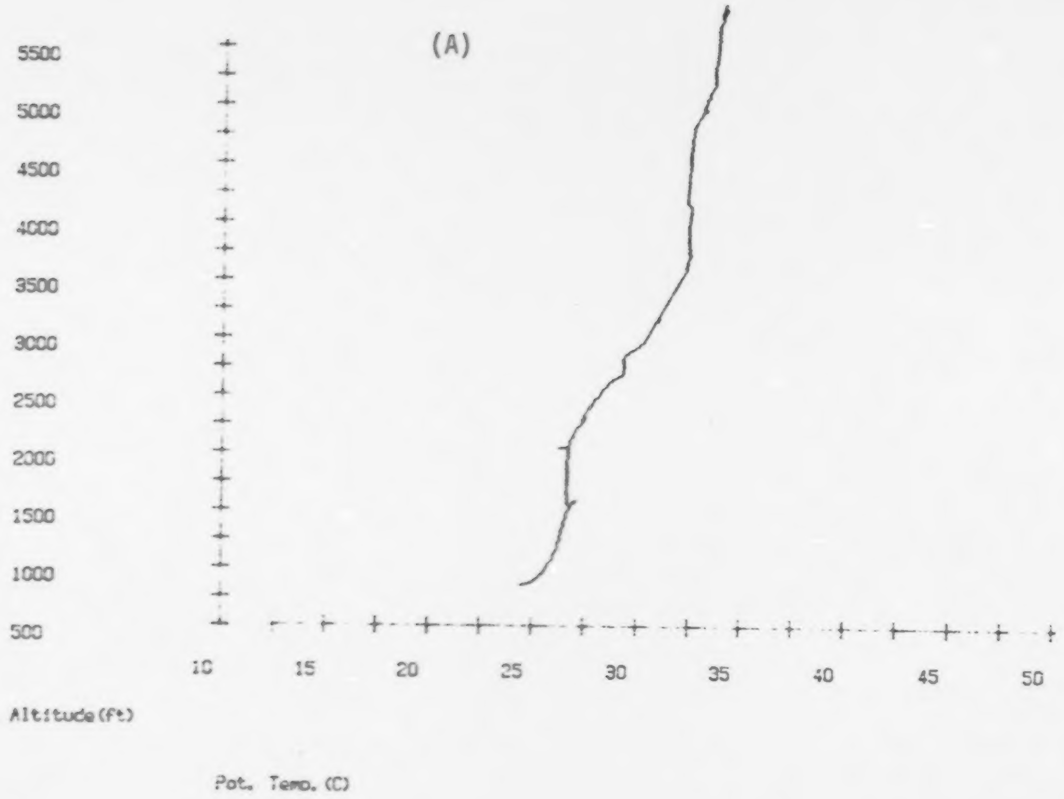
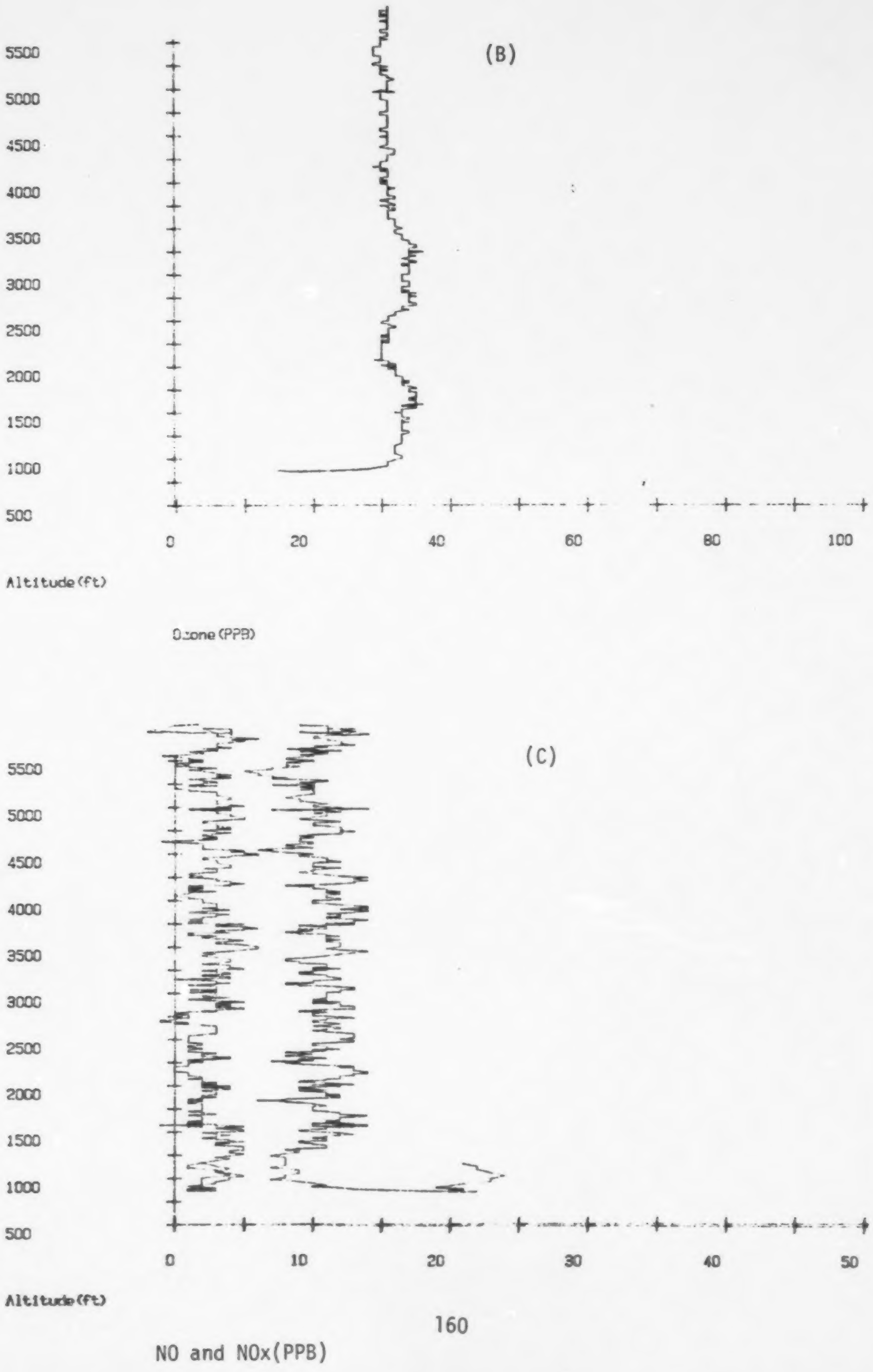
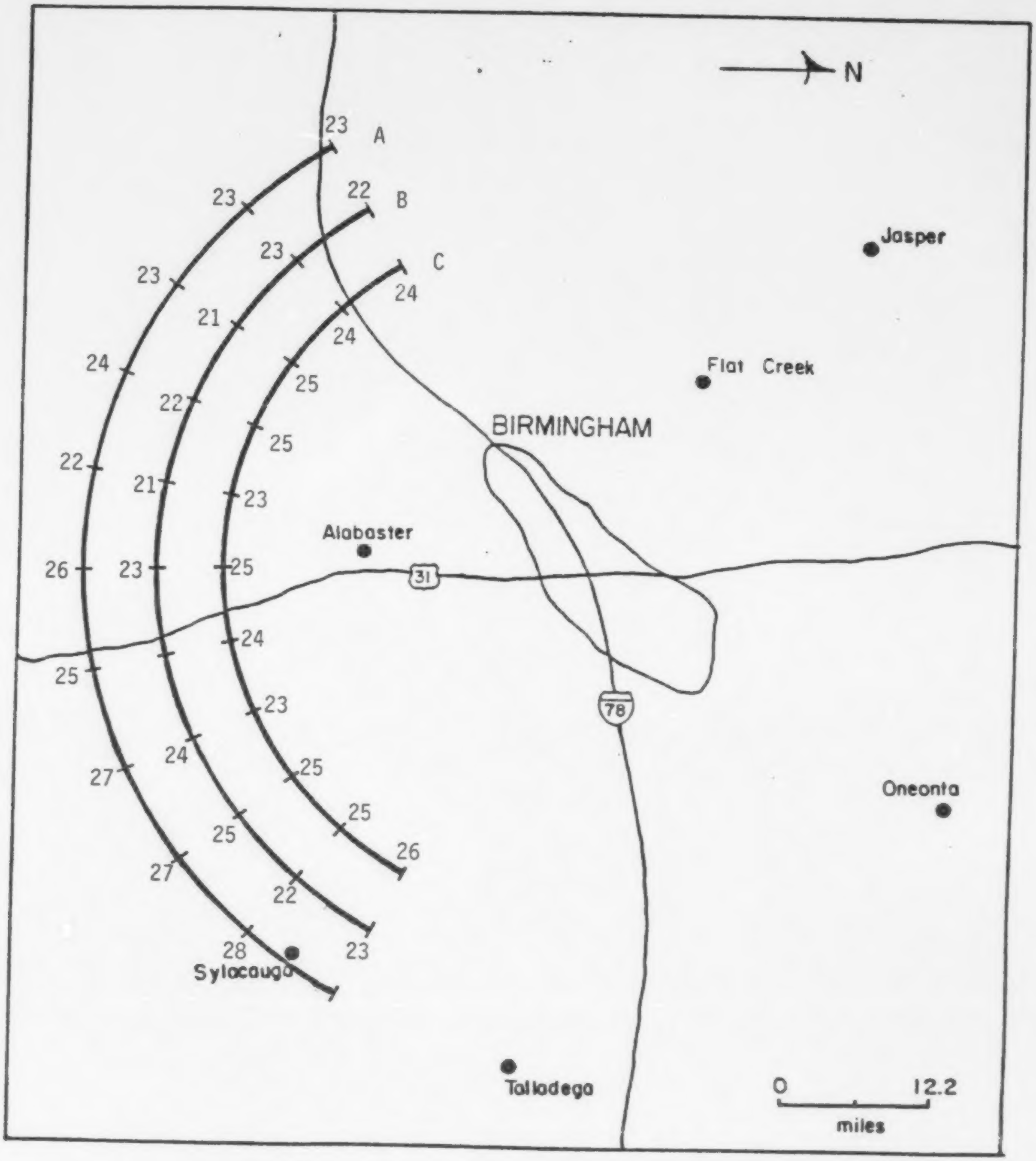


Figure D-2. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on August 26, 1985.

(Figure D-2. cont'd.)




N
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26
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28
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23
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22
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23
24
25
22
23
24
24
25
25
23
25
24
23
25
25
26
Jasper
Flat Creek
BIRMINGHAM
Alabaster
31
78
Oneonta
Sylacauga
Talladega
0
12.2
miles

Figure D-3. August 27 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude

A: 0445 - 0515 at 3000'
B: 0518 - 0545 at 4000'
C: 0549 - 0619 at 3000'

Wind: 180° at 14 knots

August 27,1985

Morning Mixing Level: 2100 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/120	3000'	04:45					43.6	<1.1	<0.4
A/132		04:48:03	28	2	7	23.2			
A/144		04:50:53	27	1	8	22.7			
A/156		04:53:54	27	1	8	23.3			
A/168		04:56:55	25	1	9	23.2			
A/180		04:59:55	26	2	9	22.9			
A/192		05:02:55	22	1	10	22.4			
A/204		05:05:45	24	1	9	21.9			
A/216		05:08:45	23	1	9	21.9			
A/228		05:11:45	23	2	9	21.9			
A/240		05:14:36	23	1	8	21.9			
B/240	4000'	05:18:59	22	1	8	20.9	4.7	<1.4	<0.6
B/228		05:21:31	23	1	8	20.3			
B/216		05:24	21		9				
B/204		05:27	22		6				
B/192		05:29	21		8				
B/180		05:32	23		6				
B/168		05:35			-				
B/156		05:37	24		7				
B/144		05:40	25		7				
B/132		05:42	22		7				
B/120		05:45	23		7				
C/120	3000'	05:49:54	26	1	7	23.0	15.6	<0.7	<0.3
C/132		05:52:45	25	2	9	22.7			
C/144		05:55:47	25	1	8	22.7			
C/156		05:58:47	23	1	9	22.7			
C/168		06:01:37	24	1	7	22.6			
C/180		06:04:37	25	2	8	22.5			
C/192		06:07:37	23	2	9	22.5			
C/204		06:10:29	25	1	7	22.4			
C/216		06:13:30	25	1	9	22.1			
C/228		06:16:31	24	1	7	21.9			
C/240		06:19:11	24	1	8	22.0			

* See flight map for Arc; Radial off Birmingham City Center.

Table D-2. Hydrocarbon Concentrations (ppbC) in Samples Collected on August 27, 1985

Hydrocarbon	A/C Arc A 0455 - 0503 (EDT)	A/C Arc B 0529 - 0537 (EDT)	A/C Arc C 0700 - 0708 (EDT)
Ethane	2.0	1.7	1.7
Ethylene	(0.5)	(0.1)	(0.1)
Acetylene	0.2	-	-
Propane	3.0	0.8	0.8
Propene	0.2	-	-
i-Butane	11.4	0.6	0.6
n-Butane	2.4	0.2	0.3
i-Pentane	4.2	0.3	2.0
n-Pentane	1.6	0.2	0.4
Cyclopentane	-	-	-
Isoprene	1.8	0.2	0.1
2,3-Dimethylbutane	-	-	0.3
2-Methylpentane	0.9	-	0.2
3-Methylpentane	0.5	-	0.1
n-Hexane	0.5	-	0.1
Methylcyclopentane	0.4	-	-
Benzene	0.7	0.2	0.2
Cyclohexane	-	-	-
2-Methylhexane	0.7	-	0.1
3-Methylhexane	0.4	-	3.4
2,2,4-Trimethylpentane	2.3	0.4	1.1
Toluene	5.8	-	1.8
n-Octane	0.3	-	-
Ethylbenzene	0.7	-	0.3
p & *m*-Xylene	2.5	-	1.2
o-Xylene	0.6	-	0.8
Total Identified HC	43.6	4.7	15.6
TOTAL NMHC	66.6	5.8	42.1
% Paraffins	70	80	71
% Olefins	6	7	1
% Aromatics	24	13	28

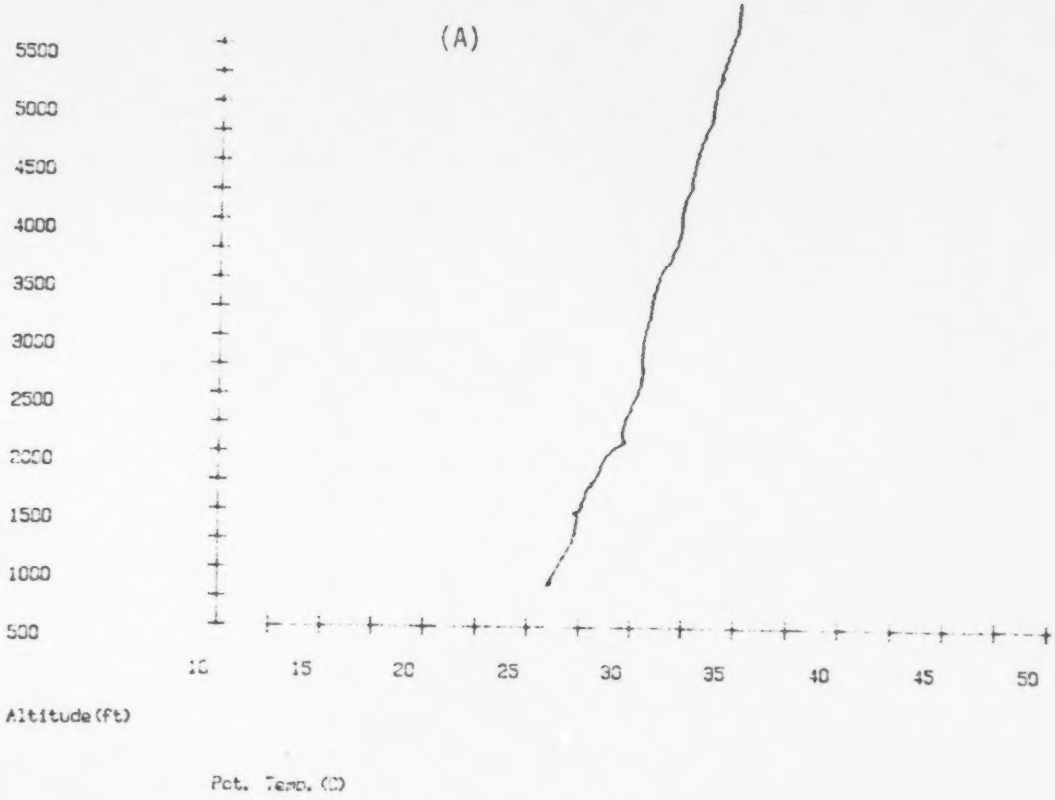
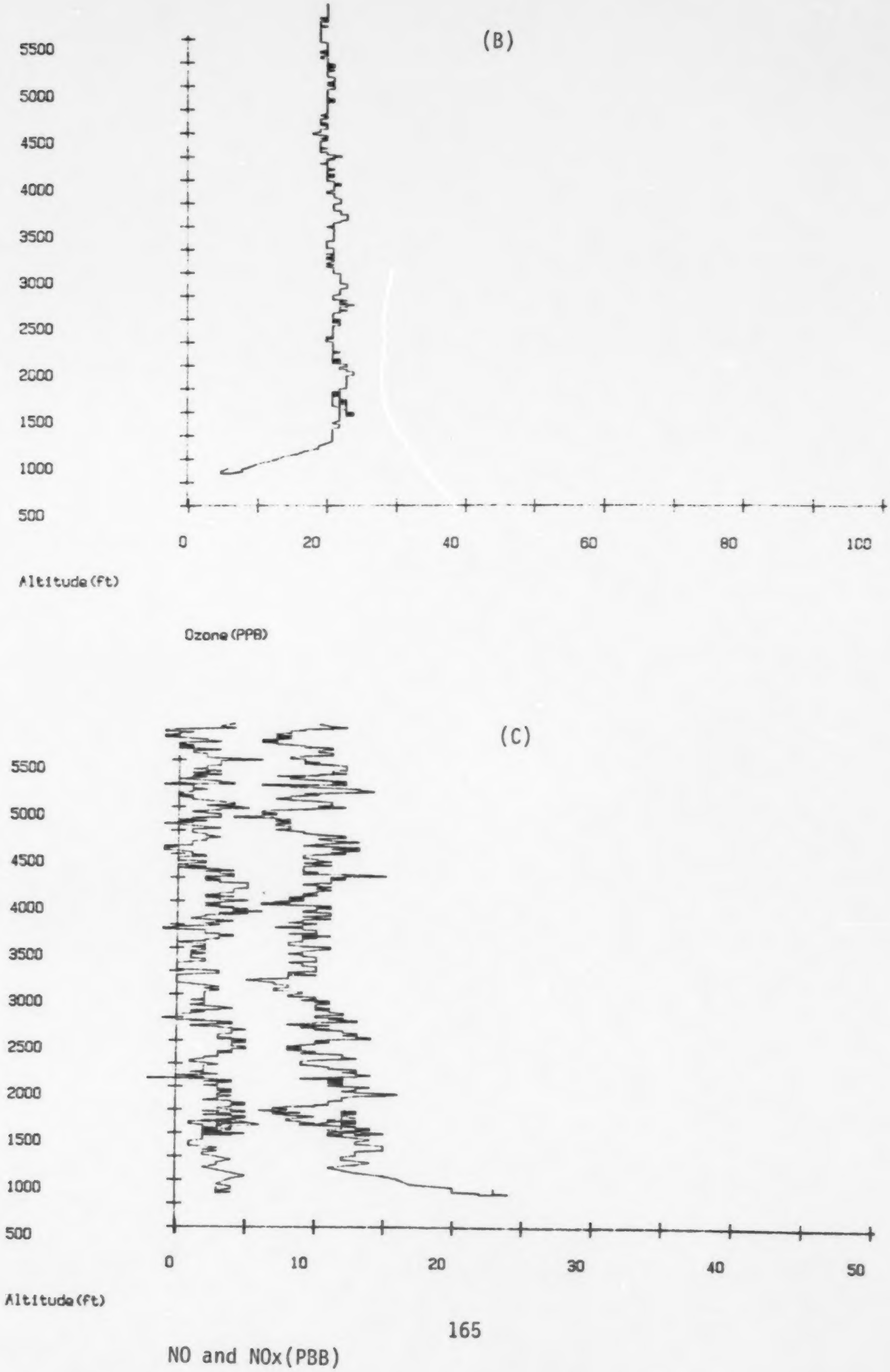
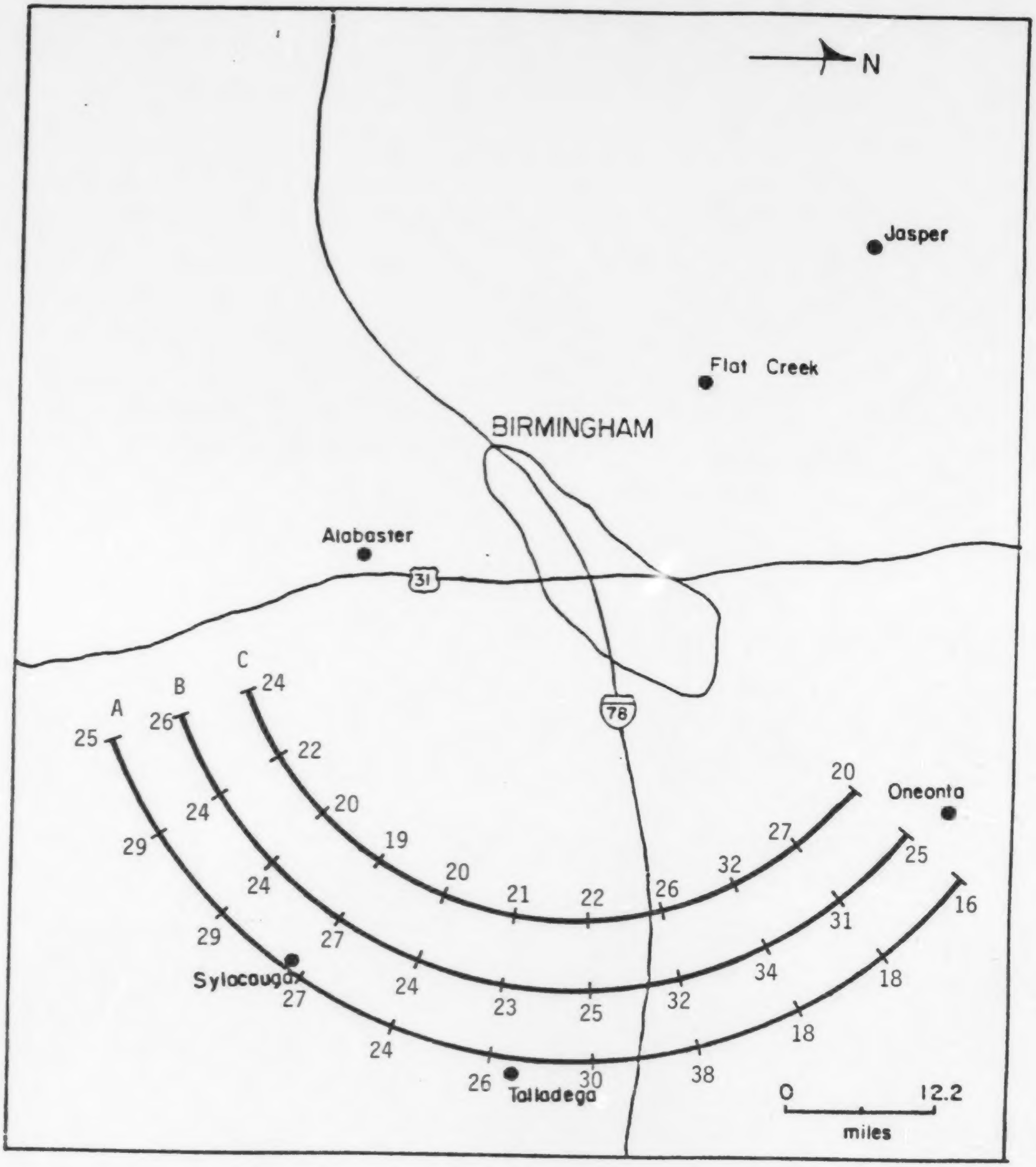


Figure D-4. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on August 27, 1985.

(Figure D-4. cont'd.)




N
Jasper
Flat Creek
BIRMINGHAM
Alabaster
31
78
Oneonta
Sylacauga
Talladega
A
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34
31
25
24
22
20
19
20
21
22
26
32
27
20
0
12.2
miles

Figure D-5. August 28 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude

A: 0441 - 0511 at 3000'
B: 0519 - 0547 at 4000'
C: 0553 - 0621 at 3000'

Wind: 100^{o} at 10 knots

August 28, 1985

Morning Mixing Level: 1600 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/160	3000'	04:41:37	25	3	18	22.4	14.4	<0.7	<0.3
A/148		04:44:17	29	1	16	22.4			
A/136		04:47:17	29	2	15	22.5			
A/124		04:50:07	27	2	13	22.7			
A/112		04:52:57	24	3	17	22.8			
A/100		04:55:57	26	1	14	22.9			
A/088		04:58:47	30	2	13	23.1			
A/076		05:01:37	38	1	10	23.2			
A/064		05:04:27	18	2	11	23.7			
A/052		05:07:27	18	2	6	23.7			
A/040		05:10:08	16	0	6	23.9			
B/040	4000'	05:19:22	25	1	10	21.0	9.0	<0.8	<0.3
B/052		05:22:13	31	2	10	20.7			
B/064		05:24:53	34	1	11	20.4			
B/076		05:27:43	32	2	13	20.2			
B/088		05:30:23	25	0	10	20.4			
B/100		05:33:13	23	2	8	20.5			
B/112		05:36:03	24	2	10	20.6			
B/124		05:38:43	27	0	9	20.5			
B/136		05:41:33	24	2	10	20.4			
B/148		05:44:23	24	2	8	20.5			
B/160		05:47:03	26	3	10	20.2			
C/160	3000'	05:53:05	24	2	14	22.1	12.1	<0.9	<0.3
C/148		05:55:45	22	0	16	22.1			
C/136		05:58:35	20	2	16	22.2			
C/124		06:01:25	19	0	19	22.4			
C/112		06:04:15	20	2	17	22.4			
C/100		06:07:05	21	1	14	22.5			
C/088		06:10	22		11				
C/076		06:13	26		10				
C/064		06:16	32		10				
C/052		06:19	27		11				
C/040		06:21	20		15				

* See flight map for Arc; Radial off Birmingham City Center.

Table D-3. Hydrocarbon Concentrations (ppbC) in Samples Collected on August 28, 1985

Hydrocarbon	A/C Arc A 0451 - 0459 (EDT)	A/C Arc B 0529 - 0537 (EDT)	A/C Arc C 0603 - 0611 (EDT)
Ethane	1.7	2.3	1.7
Ethylene	(0.2)	(0.2)	(0.2)
Acetylene	0.5	0.2	0.4
Propane	1.2	1.3	1.0
Propene	0.2	0.2	0.1
i-Butane	0.7	0.6	0.4
n-Butane	2.0	0.8	1.4
i-Pentane	1.8	0.4	1.4
n-Pentane	0.7	0.2	0.7
Cyclopentane	0.4	-	0.3
Isoprene	-	0.7	-
2,3-Dimethylbutane	-	-	-
2-Methylpentane	0.6	0.2	0.4
3-Methylpentane	0.4	-	0.2
n-Hexane	0.4	-	0.3
Methylcyclopentane	0.2	-	0.2
Benzene	0.6	0.4	0.6
Cyclohexane	-	-	-
2-Methylhexane	-	-	-
3-Methylhexane	0.2	-	0.2
2,2,4-Trimethylpentane	-	-	-
Toluene	1.5	0.7	1.4
n-Octane	-	-	-
Ethylbenzene	0.4	0.2	0.3
p & *m*-Xylene	0.5	0.2	0.6
o-Xylene	0.2	0.4	0.3
Total Identified HC	14.4	9.0	12.1
TOTAL NMHC	15.0	10.7	12.8
% Paraffins	72	65	70
% Olefins	3	12	2
% Aromatics	22	21	25

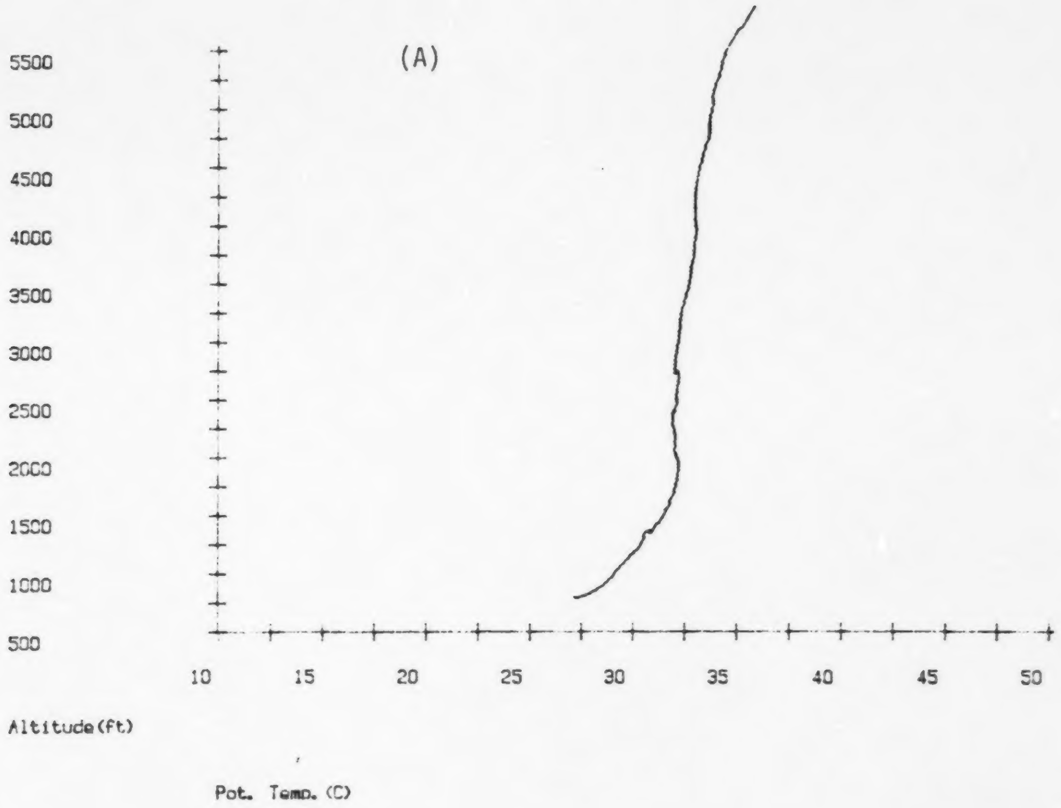
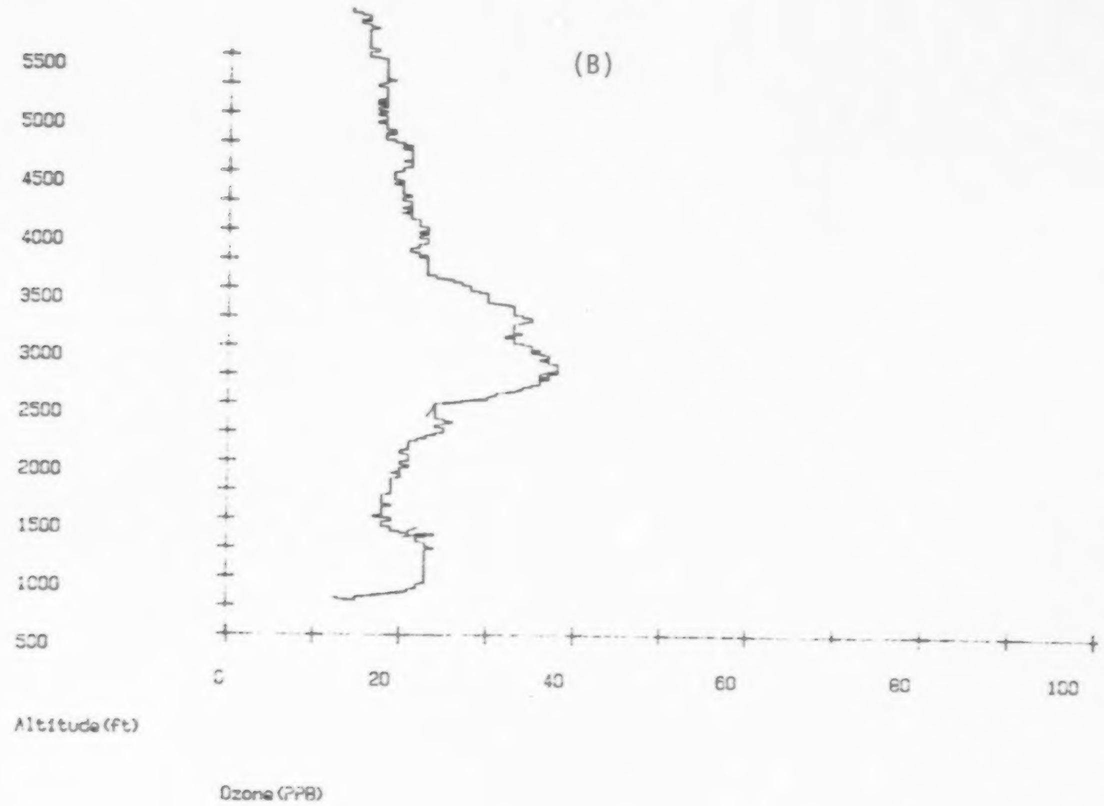
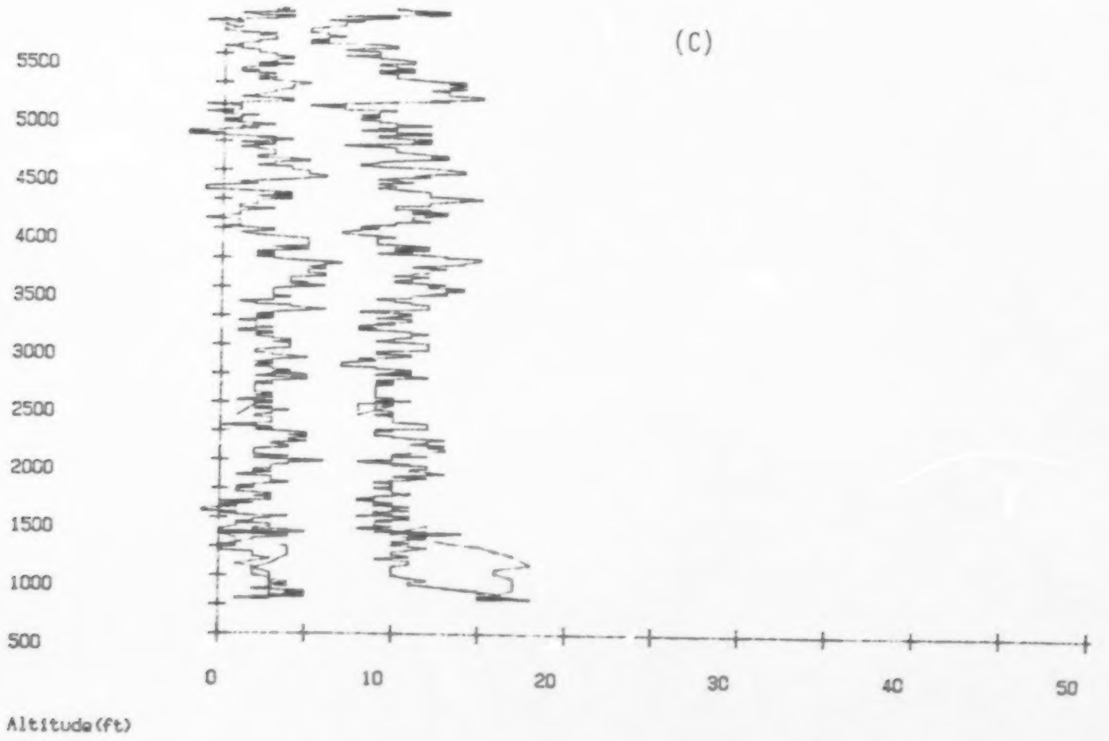
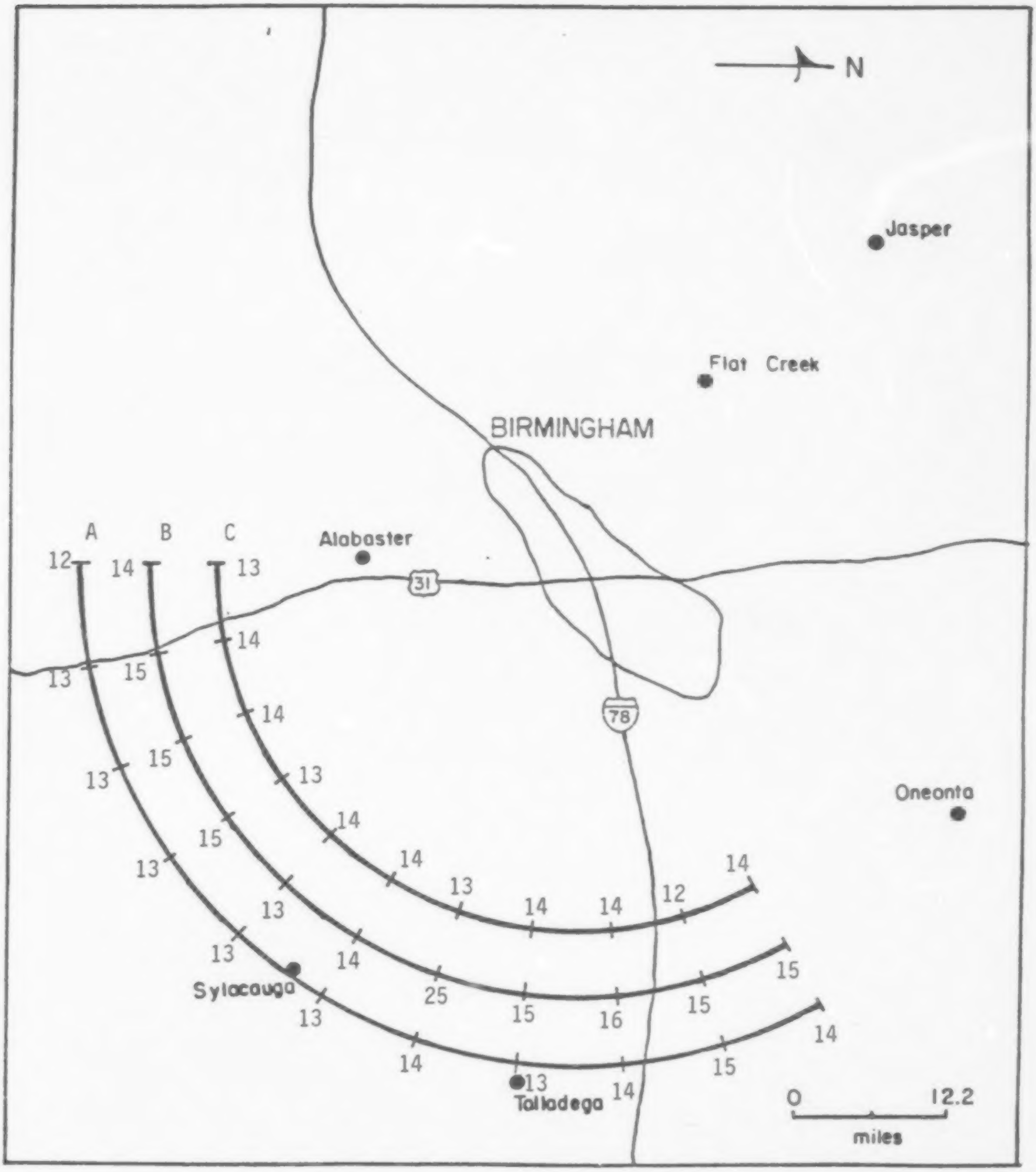


Figure D-6. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on August 28, 1985.

(Figure D-6. cont'd.)






N
Jasper
Flat Creek
BIRMINGHAM
Alabaster
31
78
Oneonta
Sylacauga
Talladega
A
B
C
12
14
13
13
15
14
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12
14
13
14
25
15
16
15
15
13
14
13
14
15
14
0
12.2
miles

Figure D-7. August 29 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude

A: 0435 - 0503 at 3000'
B: 0511 - 0539 at 4000'
C: 0542 - 0611 at 3000'

Wind: 120° at 14 knots

August 29, 1985

Morning Mixing Level: 1700 ft.

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (CDT)	O_3 (ppb)	NO (ppb)	NO_x (ppb)	Temp (°C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/180		04:35:09	12	1	11	22.8			
A/168		04:37:59	13	3	10	23.3			
A/156		04:40:40	13	2	10	23.1			
A/144		04:43:40	13	2	13	23.3			
A/132		04:46:30	13	3	8	23.3			
A/120	3000'	04:49:20	13	1	10	23.4	6.8	1.1	0.2
A/108		04:52:10	14	1	10	23.1			
A/096		04:55:01	13	2	9	23.4			
A/084		04:57:51	14	2	8	22.9			
A/072		05:00:41	15	1	9	23.4			
A/060		05:03:31	14	2	8	22.8			
B/060		05:11:23	15	2	11	21.4			
B/072		05:14:03	15	2	8	21.5			
B/084		05:16:53	16	4	7	21.8			
B/096		05:19:43	15	2	10	22.0	3.8		
B/108		05:22:23	25	2	8	21.7			
B/120	4000'	05:25:13	14	1	7	22.2		1.1	0.1
B/132		05:28:03	13	0	9	22.3			
B/144		05:30:53	15	2	9	21.9	4.2		
B/156		05:33:33	15	2	7	21.7			
B/168		05:36:24	15	2	9	21.6			
B/180		05:39:04	14	1	8	21.5			
C/180		05:42:55	13	0	9	23.3			
C/168		05:45:35	14	2	8	23.5			
C/156		05:48:26	14	1	8	23.4			
C/144		05:51:16	13	1	7	23.3			
C/132		05:53:56	14	2	8	23.3			
C/120	3000'	05:56:56	14	1	9	23.3	3.4	1.4	0.1
C/108		05:59:26	13	1	8	23.2			
C/096		06:02:17	14	1	9	23.1			
C/084		06:05:07	14	2	10	23.4			
C/072		06:07:48	12	1	10	23.4			
C/060		06:10:28	14	3	9	22.8			

* See flight map for Arc; Radial off Birmingham City Center.

Table D-4. Hydrocarbon Concentrations (ppbC) in Samples Collected on August 29, 1985

Hydrocarbon	A/C Arc A 0445 - 0453 (EDT)	A/C Arc B 0521 - 0529 (EDT)	A/C Arc B 0553 - 0601 (EDT)	A/C Arc C 0605 - 0606 (EDT)
Ethane	1.5	1.3	1.1	1.0
Ethylene	(0.1)	(0.1)	-	-
Acetylene	0.1	-	0.1	-
Propane	0.6	0.5	0.3	0.3
Propene	0.1	0.2	0.1	-
i-Butane	0.7	1.1	0.6	0.3
n-Butane	0.3	0.3	0.2	0.2
i-Pentane	0.4	-	0.2	0.2
n-Pentane	0.3	-	-	0.2
Cyclopentane	-	-	-	-
Isoprene	1.1	-	0.6	0.6
2,3-Dimethylbutane	-	-	-	-
2-Methylpentane	0.1	-	-	-
3-Methylpentane	-	-	-	-
n-Hexane	-	-	-	-
Methylcyclopentane	-	-	-	-
Benzene	0.1	-	-	0.2
Cyclohexane	-	-	-	-
2-Methylhexane	-	-	-	-
3-Methylhexane	-	-	-	-
2,2,4-Trimethylpentane	-	-	-	-
Toluene	0.6	0.3	0.6	0.2
n-Octane	-	-	-	-
Ethylbenzene	0.2	-	0.1	-
p & *m*-Xylene	0.4	-	0.2	-
o-Xylene	0.2	-	0.1	0.2
Total Identified HC	6.8	3.8	4.2	3.4
TOTAL NMHC	14.3	7.0	7.5	4.2
% Paraffins	58	84	57	64
% Olefins	19	8	17	18
% Aromatics	22	8	24	18

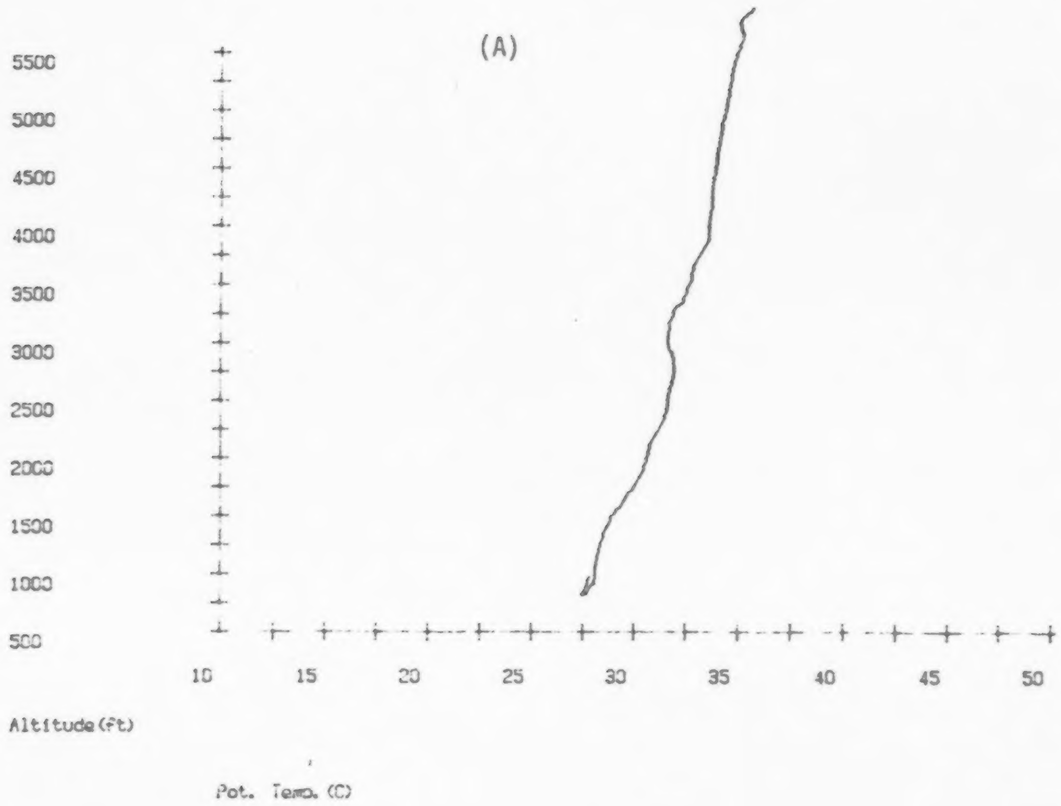
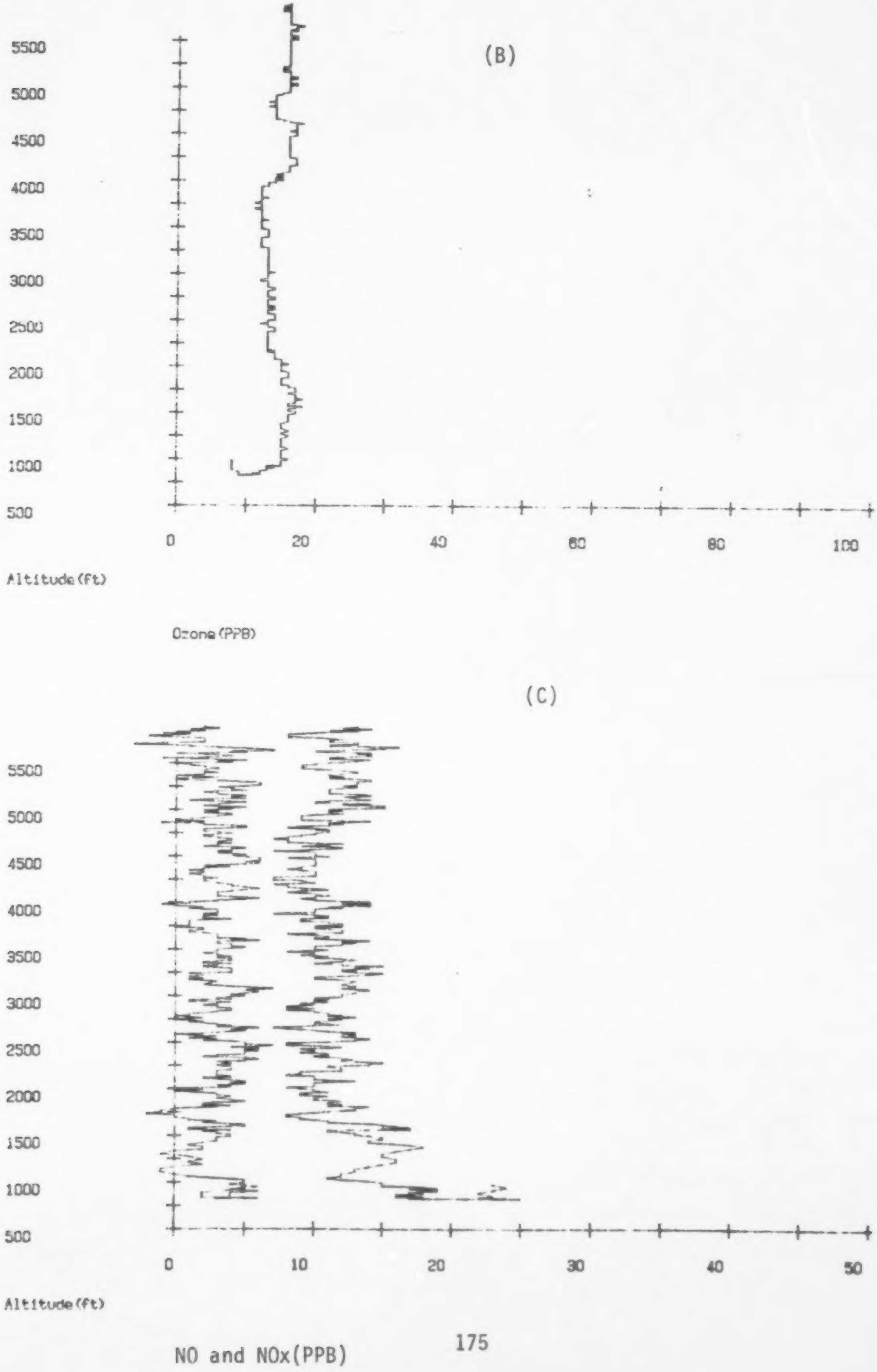


Figure D-8. Potential Temperature (A), ozone (B) and oxides of nitrogen (C) changes with altitude on August 29, 1985.

(Figure D-8. cont'd.)



APPENDIX E

Aircraft Flight Maps and Pollutant Measurement Data Obtained from Philadelphia, Pennsylvania

PHILADELPHIA AIR QUALITY DATA

This section provides a tabulation of airborne data collected in the Philadelphia area during the period July 8 and August 6, 1986. For each sampling day, there is a flight map with ozone concentrations marked along the route, a tabulation of air quality data, a listing of individual hydrocarbon concentrations and a graphical summary of ozone, NO_x and temperature changes with altitude.

NOTES on Hydrocarbon Tables

* Means data not available

- Means concentration less than 0.1 ppbC

( ) Ethylene values in parentheses were calculated by multiplying the propane concentration by 0.18. This was necessary in cases of obvious ethylene contamination due to the presence of a chemiluminescent ozone analyzer. The ethylene-propane ratio was derived from airborne samples that were free of contamination problems.

TNMHC is the sum of all gas chromatographic peaks

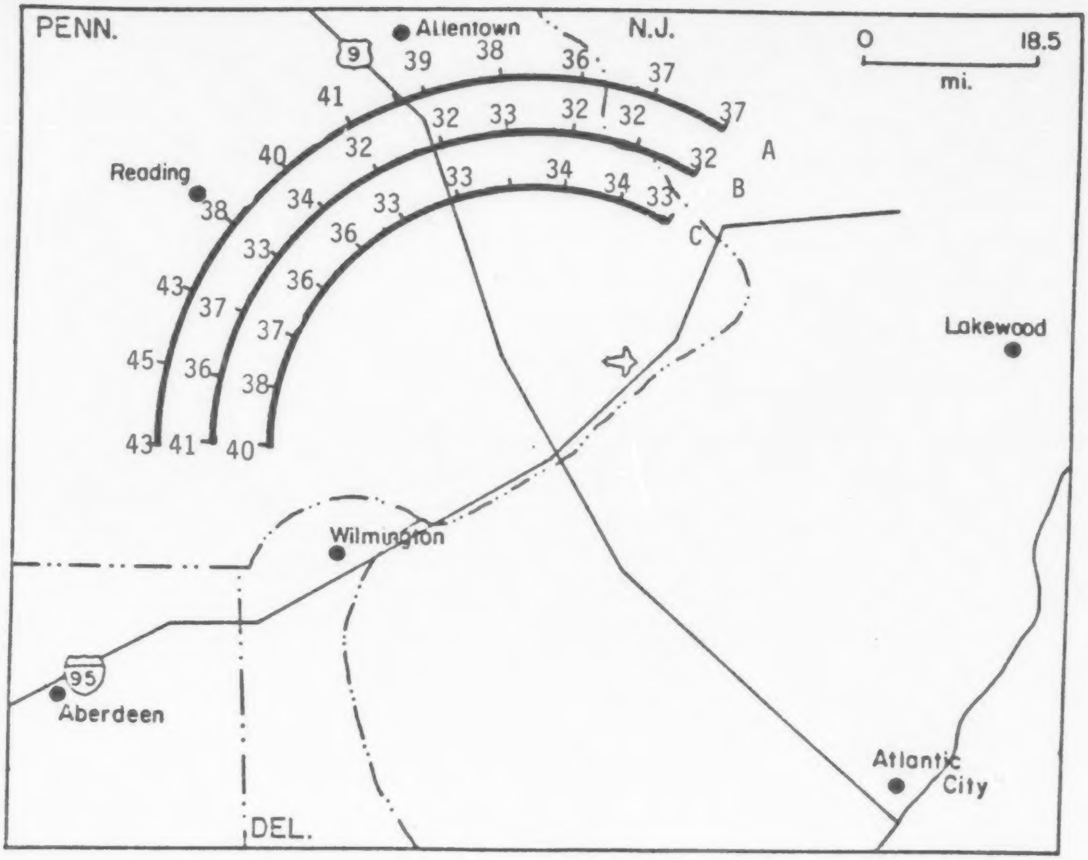

PENN.
Allentown
N.J.
9
0
18.5
mi.
39
38
36
37
41
32
33
32
32
37
A
40
32
32
B
Reading
33
34
34
33
38
34
33
C
33
36
43
36
37
Lakewood
37
45
36
38
43
41
40
Wilmington
95
Aberdeen
Atlantic City
DEL.

Figure E-1. July 8, 1986 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude (AGL)

A: 0704 - 0733 at 2000'

B: 0742 - 0813 at 3000'

C: 0825 - 0851 at 3000'

Wind: 330° at 20 knots

July 8, 1986

Morning Mixing Level: 1500 feet

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (EDT)	O3 (ppb)	NO (ppb)	NOx (ppb)	Temp (C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/040	2000	07:04:00	37	2	9	22.9	22.8		
A/028		07:06:47	37	2	10	22.9			
A/016		07:09:43	36	2	8	22.8			
A/004		07:12:38	38	3	8	22.6			
A/352		07:15:33	39	2	10	22.3			
A/340		07:18:29	41	1	9	22.6			
A/328		07:21:24	40	0	9	23.2			
A/316		07:24:19	38	1	14	23.8			
A/304		07:27:14	43	1	7	23.3			
A/292		07:30:10	45	2	8	22.7			
A/280		07:32:58	43	1	10	22.9			
B/280	3000	07:42:26	41	0	9	20.9	33.9		
B/292		07:45:26	36	0	7	20.3			
B/304		07:48:33	37	1	7	20.0			
B/316		07:51:41	33	-1	7	21.1			
B/328		07:54:48	34	0	5	20.8			
B/340		07:57:56	32	4	5	21.9			
B/352		08:01:03	32	1	6	21.2			
B/004		08:04:11	33	3	7	20.7			
B/016		08:07:18	32	1	6	20.0			
B/028		08:10:26	32	3	7	20.0			
B/040		08:13:26	32	-2	5	21.5			
C/040	3000	08:24:45	33	1	4	21.6	17.1		
C/028		08:27:16	34	1	3	21.4			
C/016		08:29:56	34	0	5	19.6			
C/004		08:32:35		1	3	19.5			
C/352		08:35:15	33	0	5	20.0			
C/340		08:37:54	33			19.7			
C/328		08:40:33	36	1	6	19.6			
C/316		08:43:13	36	1	7	19.5			
C/304		08:45:52	37	1	6	19.3			
C/292		08:48:32	38	0	8	19.5			
C/280		08:51:04	40	-1	8	19.3			

* See flight map for Arc; Radial from Philadelphia city centre.

Table E-1. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 8, 1986

Hydrocarbon	A/C Arc A 0704 - 0733 (EDT)	A/C Arc B 0742 - 0813 (EDT)	A/C Arc C 0824 - 0851 (EDT)
Ethane	3.9	4.2	2.8
Ethylene	0.2	-	-
Acetylene	0.4	0.2	0.3
Propane	2.7	1.4	1.5
Propene	-	-	-
i-Butane	0.8	0.3	0.4
n-Butane	2.3	1.1	1.3
i-Pentane	1.9	0.6	1.0
n-Pentane	1.0	0.4	0.4
Cyclopentane	-	-	-
Isoprene	-	-	-
2,3-Dimethylbutane	-	-	-
2-Methylpentane	0.4	0.1	0.2
3-Methylpentane	0.2	-	-
n-Hexane	0.4	0.1	0.2
Methylcyclopentane	0.1	-	-
Benzene	1.2	0.6	1.0
Cyclohexane	-	-	-
2-Methylhexane	-	-	-
3-Methylhexane	0.1	-	0.1
2,2,4-Trimethylpentane	-	-	-
Toluene	4.3	5.0	3.7
n-Octane	-	-	-
Ethylbenzene	0.7	2.3	0.7
p & *m*-Xylene	2.1	11.2	2.1
o-Xylene	0.1	6.4	1.4
Total Identified HC	22.8	33.9	17.1
TOTAL NMHC	26.9	91.9	22.5
% Paraffins	59	24	46
% Olefins	1	-	-
% Aromatics	39	75	52

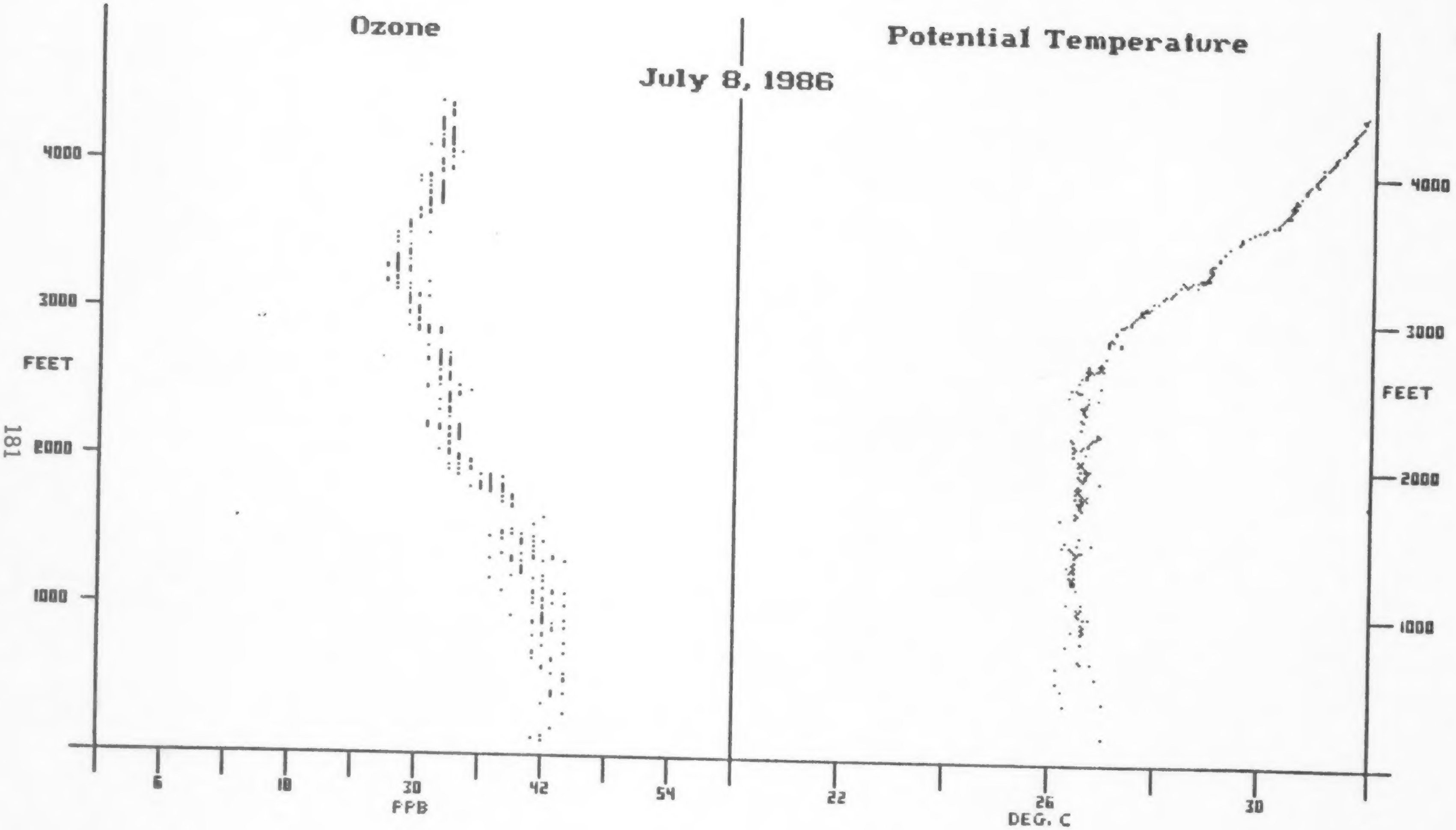
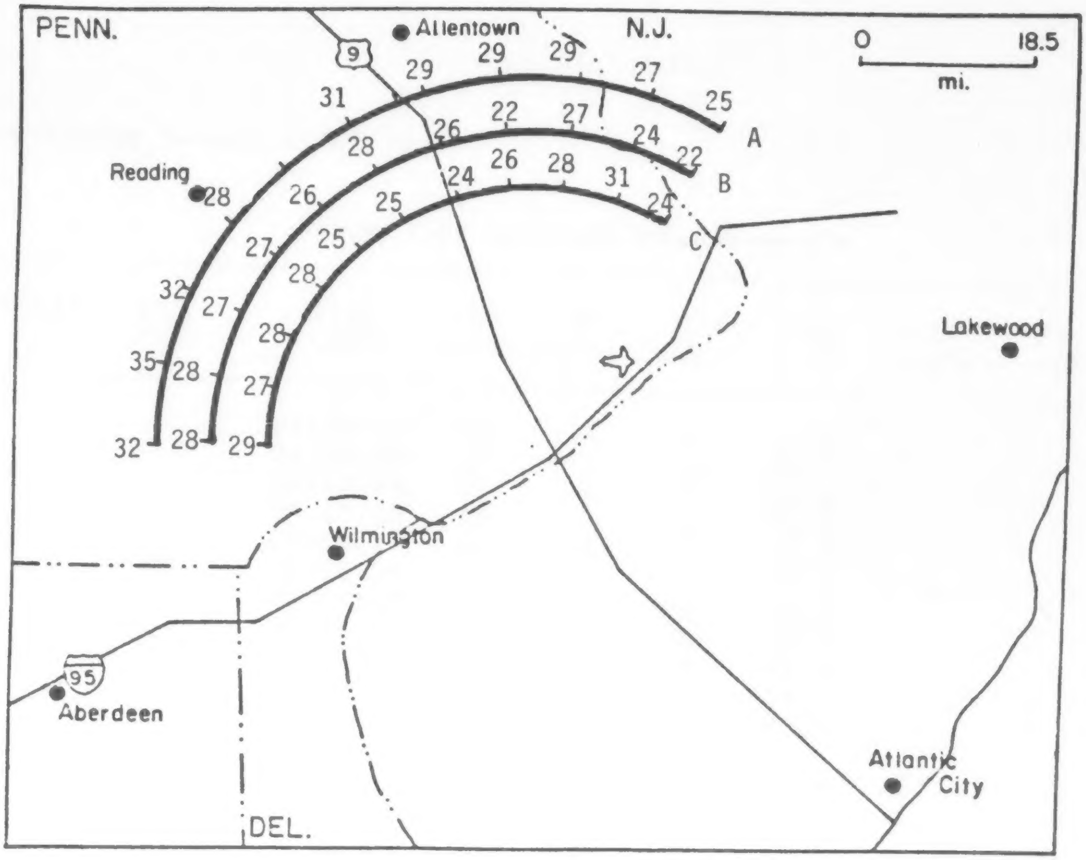


Figure E-2. Potential temperature and ozone changes with altitude on July 8, 1986.


PENN.
Allentown
N.J.
0
18.5
mi.
9
Reading
Lakewood
Wilmington
95
Aberdeen
Atlantic City
DEL.
A
B
C
29
29
29
27
25
31
26
22
27
24
22
28
28
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35
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32
28
29

Figure E-3. July 10, 1986 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude (AGL)

A: 0539 - 0611 at 2000'

B: 0617 - 0645 at 3000'

C: 0651 - 0717 at 2500'

Wind: 330° at 10 knots

July 10, 1986

Morning Mixing Level: <1000 feet

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (EDT)	O3 (ppb)	NO (ppb)	NOx (ppb)	Temp (C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/040	2000	05:39:30	25	2	6	19.0	26.7	1.9	0.9
A/028		05:42:35	27	2	10	18.7			
A/016		05:45:48	29	4	7	18.6			
A/004		05:49:00	29	3	5	18.9			
A/352		05:52:13	29	5	5	18.7			
A/340		05:55:26	31	3	4	18.6			
A/328		05:58:39		2	9	18.2			
A/316		06:01:52	28	4	15	18.4			
A/304		06:05:04	32	4	9	18.8			
A/292		06:08:17	35	4	8	19.3			
A/280		06:11:23	32	3	7	20.3			
B/280	3000	06:16:56	28	3	3	18.4	16.8	1.6	0.8
B/292		06:19:40	28	3	6	16.7			
B/304		06:22:32	27	3	6	16.7			
B/316		06:25:24	27	4	5	17.5			
B/328		06:28:16	26	2	3	18.1			
B/340		06:31:09	28	2	4	18.4			
B/352		06:34:01	26	3	3	18.6			
B/004		06:36:53	22	5	6	18.4			
B/016		06:39:45	27	3	5	17.6			
B/028		06:42:37	24	3	3	18.1			
B/040		06:45:22	22	5	5	18.5			
C/040	2500	06:51:10	24	3	3	18.8	10.7	1.3	0.6
C/028		06:53:40	31	4	5	17.8			
C/016		06:56:18	28	4	5	18.1			
C/004		06:58:57	26	5	5	18.0			
C/352		07:01:35	24	3	6	18.7			
C/340		07:04:13	25			18.8			
C/328		07:06:51	25	3	2	18.8			
C/316		07:09:29	28	3	4	17.9			
C/304		07:12:08	28	2	3	17.9			
C/292		07:14:46	27	3	3	17.9			
C/280		07:17:17	29	4	7	16.9			

* See flight map for Arc; Radial from Philadelphia city centre.

Table E-2. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 10, 1986

Hydrocarbon	A/C Arc A 0540 - 0611 (EDT)	A/C Arc B 0617 - 0645 (EDT)	A/C Arc C 0651 - 0717 (EDT)
Ethane	2.2	1.9	2.0
Ethylene	0.3	-	-
Acetylene	1.3	0.2	0.2
Propane	1.0	0.3	0.4
Propene	-	-	-
i-Butane	0.3	0.1	0.1
n-Butane	1.6	0.2	0.2
i-Pentane	4.5	0.2	0.3
n-Pentane	0.9	0.2	0.1
Cyclopentane	0.1	-	-
Isoprene	-	-	0.3
2,3-Dimethylbutane	1.3	-	-
2-Methylpentane	0.6	-	0.1
3-Methylpentane	0.4	-	-
n-Hexane	0.3	-	-
Methylcyclopentane	0.1	-	-
Benzene	0.6	0.4	0.4
Cyclohexane	-	-	-
2-Methylhexane	-	-	-
3-Methylhexane	0.1	-	-
2,2,4-Trimethylpentane	-	-	-
Toluene	6.1	3.7	2.6
n-Octane	-	-	-
Ethylbenzene	1.2	1.1	0.7
p & *m*-Xylene	2.8	5.4	2.3
o-Xylene	1.0	3.1	1.0
Total Identified HC	26.7	16.8	10.7
TOTAL NMHC	33.4	19.9	18.4
% Paraffins	50	17	30
% Olefins	1	-	3
% Aromatics	44	82	65

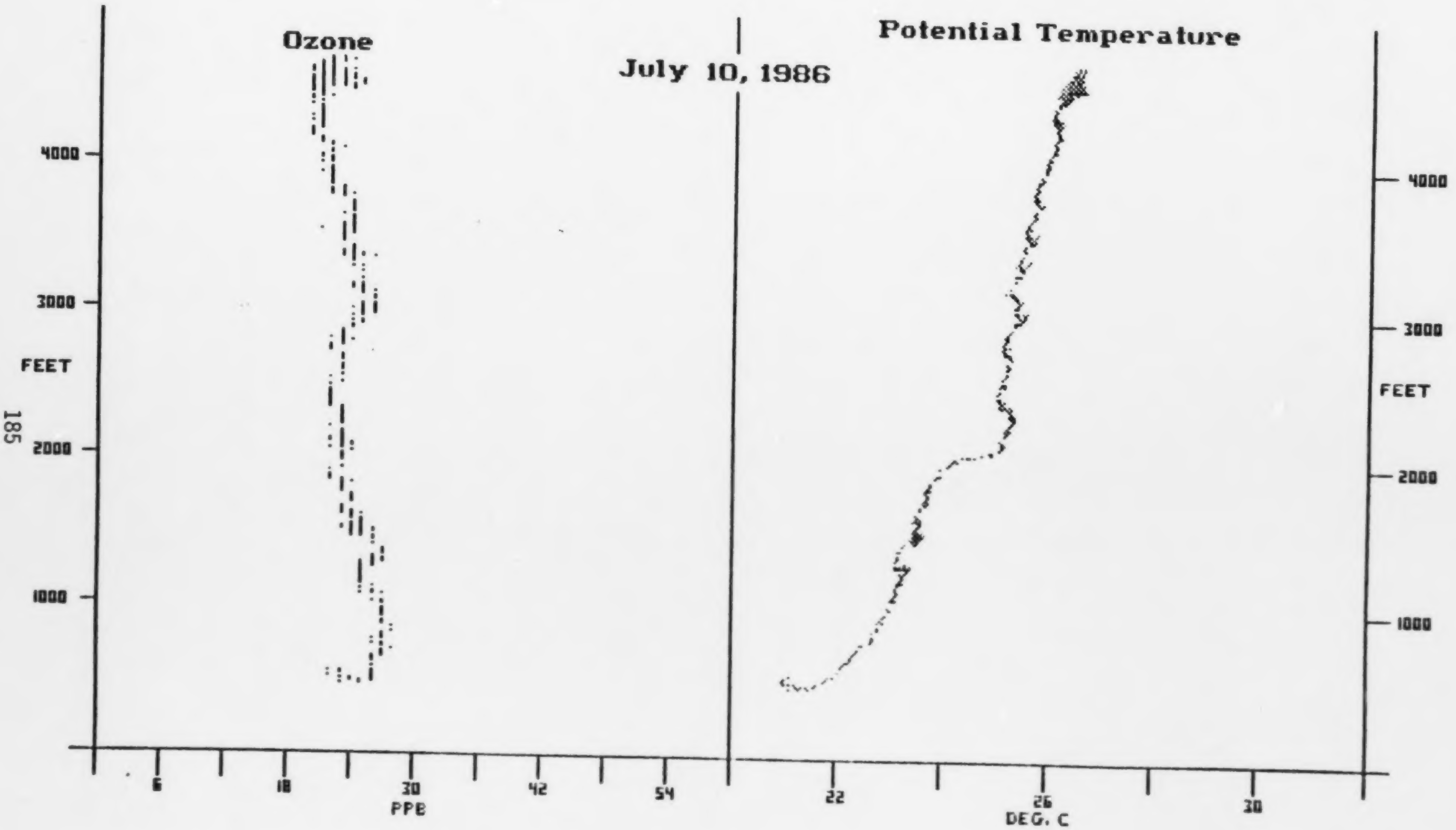
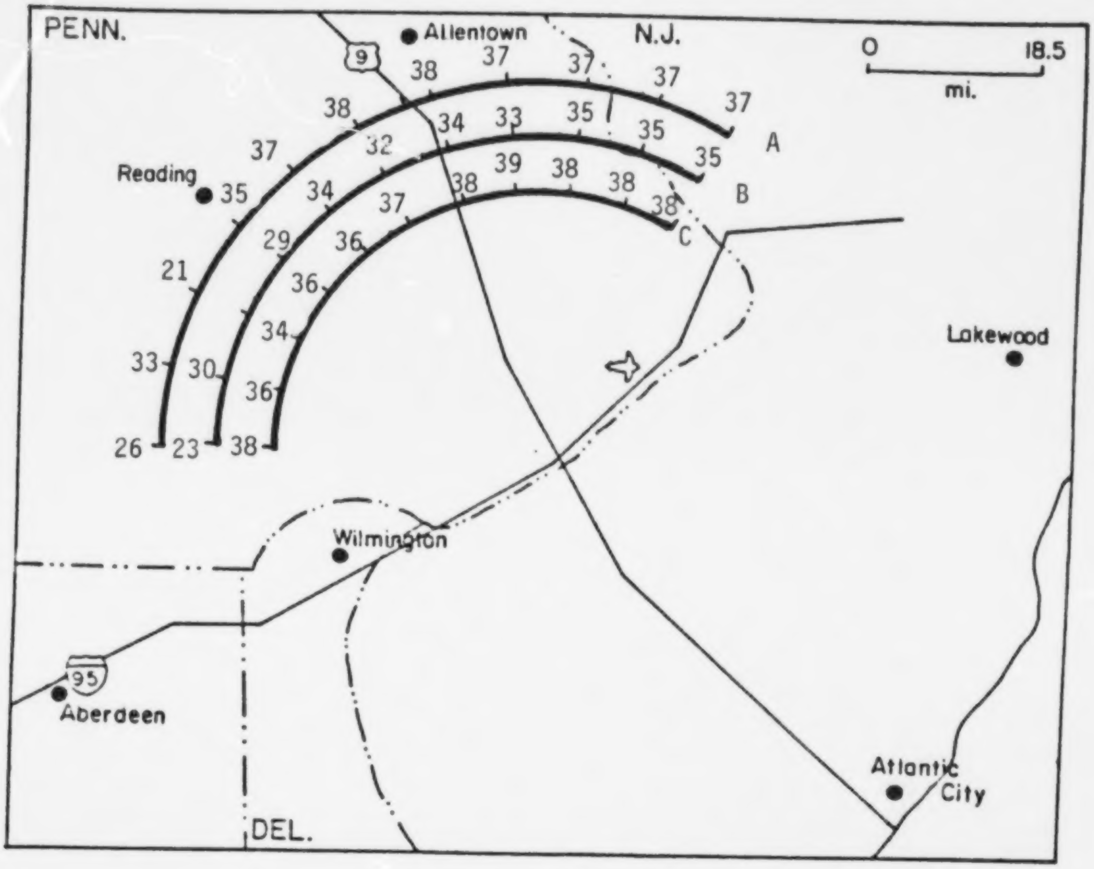


Figure E-4. Potential temperature and ozone changes with altitude on July 10, 1986.


PENN.
Allentown
N.J.
9
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38
37
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34
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B
37
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39
38
38
Reading
35
34
38
37
38
C
29
36
21
36
34
33
30
36
26
23
38
Lakewood
Wilmington
95
Aberdeen
Atlantic City
DEL.

Figure E-5. July 11, 1986 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude (AGL)

A: 0529 - 0600 at 2500'

B: 0604 - 0632 at 3500'

C: 0636 - 0708 at 2500'

Wind: 300°- 310° light & variable

July 11, 1986

Morning Mixing Level: <1000 feet

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (EDT)	O3 (ppb)	NO (ppb)	NOx (ppb)	Temp (C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/040	2500	05:29:43	37			19.9	9.1		
A/028		05:32:40	37	1	1	20.1			
A/016		05:35:45	37	1	4	20.1			
A/004		05:38:50	37	0	4	20.1			
A/352		05:41:55	38	1	2	20.0			
A/340		05:45:01	38	2	2	19.8			
A/328		05:48:06	37	2	5	19.6			
A/316		05:51:11	35	1	3	19.4			
A/304		05:54:16	21	2	32	20.1			
A/292		05:57:21	33	1	12	20.2			
A/280		06:00:19	26	1	27	20.1			
B/280	3500	06:04:02	23	3	31	18.5	18.3	2.0	0.8
B/292		06:06:43	30	2	21	18.6			
B/304		06:09:32		1	20	18.3			
B/316		06:12:21	29	2	16	17.6			
B/328		06:15:10	34	2	6	17.0			
B/340		06:18:00	32	2	8	16.2			
B/352		06:20:49	34	2	5	16.0			
B/004		06:23:38	33	4	7	16.0			
B/016		06:26:27	35	2	5	16.1			
B/028		06:29:16	35	2	6	15.9			
B/040		06:31:58	35	2	4	15.9			
C/040	2500	06:35:40	38	2	3	18.5	9.5	1.9	0.7
C/028		06:38:49	38	1	6	18.6			
C/016		06:42:05	38	2	3	18.6			
C/004		06:45:22	39	0	5	18.4			
C/352		06:48:38	38	2	4	18.5			
C/340		06:51:55	37	2	5	18.5			
C/328		06:55:11	36	2	7	18.2			
C/316		06:58:28	36	2	6	18.3			
C/304		07:01:44	34	1	6	18.5			
C/292		07:05:01	36	0	5	18.8			
C/280		07:08:10	38	4	8	19.4			

* See flight map for Arc; Radial from Philadelphia city centre.

Table E-3. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 11, 1986

Hydrocarbon	A/C Arc A 0530 - 0600 (EDT)	A/C Arc B 0604 - 0632 (EDT)	A/C Arc C 0636 - 0708 (EDT)
Ethane	2.2	2.6	2.1
Ethylene	0.1	0.2	0.1
Acetylene	0.2	0.3	0.7
Propane	0.6	1.5	0.5
Propene	-	-	-
i-Butane	0.2	0.8	0.2
n-Butane	0.5	1.2	0.5
i-Pentane	0.3	1.9	0.7
n-Pentane	0.1	0.8	0.4
Cyclopentane	-	-	-
Isoprene	-	-	-
2,3-Dimethylbutane	-	-	-
2-Methylpentane	-	0.4	0.2
3-Methylpentane	-	0.2	-
n-Hexane	-	0.3	0.1
Methylcyclopentane	-	0.1	-
Benzene	0.2	0.7	0.7
Cyclohexane	-	-	-
2-Methylhexane	-	-	-
3-Methylhexane	-	0.1	-
2,2,4-Trimethylpentane	-	-	-
Toluene	3.3	3.0	2.4
n-Octane	-	-	-
Ethylbenzene	0.3	0.6	0.2
p & *m*-Xylene	0.6	2.0	0.4
o-Xylene	0.5	1.6	0.3
Total Identified HC	9.1	18.3	9.5
TOTAL NMHC	13.7	21.3	11.5
% Paraffins	43	54	50
% Olefins	1	1	1
% Aromatics	54	43	42

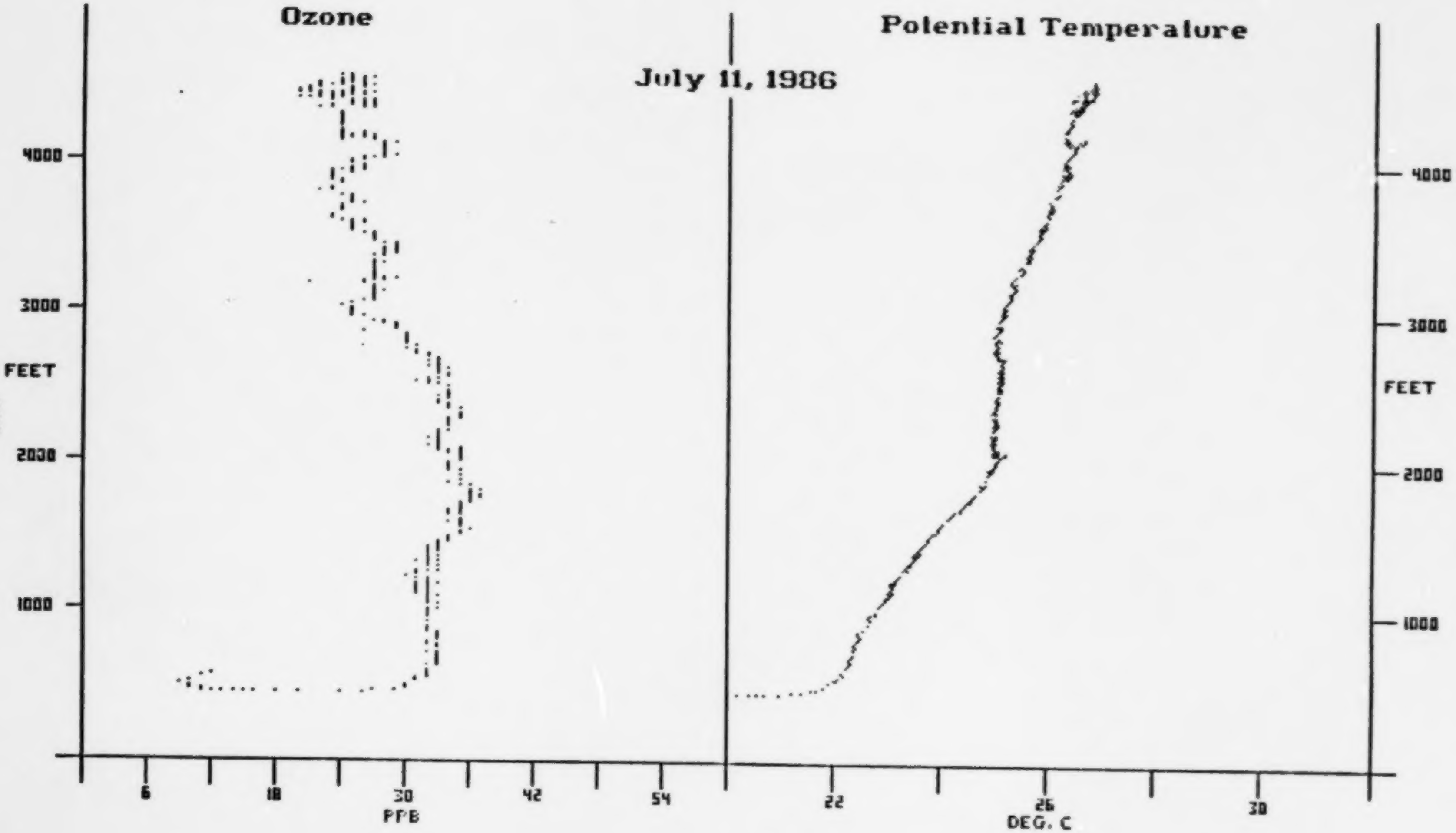

Figure E-6. Potential temperature and ozone changes with altitude on July 11, 1986.

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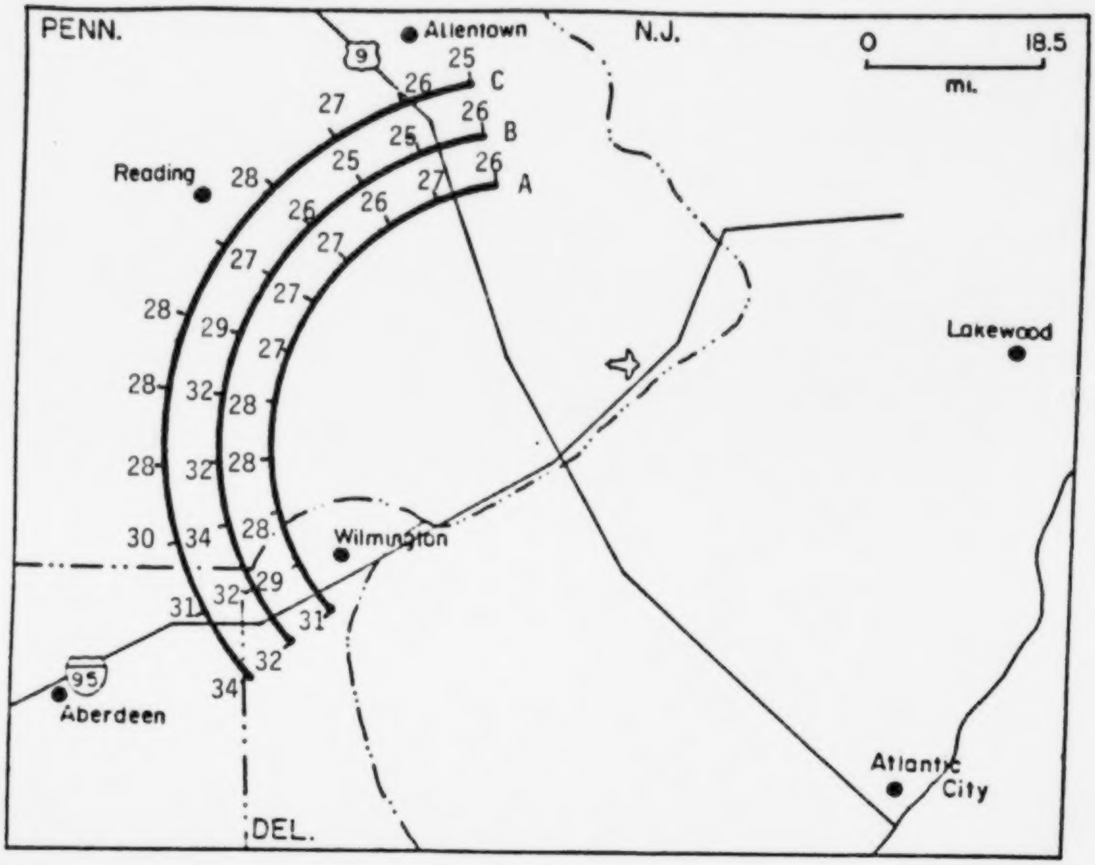

PENN.
Allentown
N.J.
0
18.5
mi.
9
C
B
A
Reading
Lakewood
Wilmington
95
Aberdeen
Atlantic City
DEL.

Figure E-7. July 14, 1986 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude (AGL)

A: 0616 - 0646 at 2500'

B: 0653 - 0724 at 3500'

C: 0728 - 0757 at 2500'

Wind: 290° at 25 knots

July 14, 1986

Morning Mixing Level: 1100 feet

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (EDT)	O3 (ppb)	NO (ppb)	NOx (ppb)	Temp (C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/360		06:15:48	25	2	3	22.2			
A/348		06:18:40	26	2	5	21.9			
A/336		06:21:41	27	2	3	21.7			
A/324		06:24:41	28	1	2	21.5			
A/312		06:27:42		2	3	21.6			
A/300	2500	06:30:42	28	2	3	21.5	20.7	1.9	0.7
A/288		06:33:42	28	2	3	21.6			
A/276		06:36:43	28	1	3	21.4			
A/264		06:39:43	30	1	3	21.6			
A/252		06:42:44	31	2	3	22.0			
A/240		06:45:37	34	2	2	23.3			
B/240		06:52:42	32	1	3	21.1			
B/252		06:55:41	32	1	2	21.0			
B/264		06:58:48	34	2	2	21.8			
B/276		07:01:55	32	2	3	21.3			
B/288		07:05:02	32	2	2	20.8			
B/300	3500	07:08:09	29	2	2	20.2	17.4	2.1	1.3
B/312		07:11:16	27	2	3	19.2			
B/324		07:14:23	26	2	5	19.4			
B/336		07:17:30	25	2	4	19.2			
B/348		07:20:37	25	2	2	19.6			
B/360		07:23:37	26	1	3	19.8			
C/360		07:28:30	26	2	3	21.6			
C/348		07:31:17	27	2	4	22.1			
C/336		07:34:12	26	3	5	21.5			
C/324		07:37:08	27	2	3	21.9			
C/312		07:40:03	27	2	3	22.0			
C/300	2500	07:42:58	27	2	5	22.0	22.2	1.6	0.9
C/288		07:45:53	28	2	3	22.2			
C/276		07:48:48	28	1	5	22.4			
C/264		07:51:44	28	3	4	22.5			
C/252		07:54:39	29	1	3	22.9			
C/240		07:57:27	31	2	3	23.6			

* See flight map for Arc; Radial from Philadelphia city centre.

Table E-4. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 14, 1986

Hydrocarbon	A/C Arc A 0616 - 0646 (EDT)	A/C Arc B 0653 - 0724 (EDT)	A/C Arc C 0729 - 0758 (EDT)
Ethane	5.0	4.3	6.5
Ethylene	0.2	-	0.1
Acetylene	0.2	0.1	0.2
Propane	2.4	2.1	3.2
Propene	-	-	-
i-Butane	0.6	0.5	0.8
n-Butane	1.9	2.3	2.4
i-Pentane	1.4	1.6	1.5
n-Pentane	0.8	0.8	1.2
Cyclopentane	-	-	-
Isoprene	-	-	-
2,3-Dimethylbutane	-	-	-
2-Methylpentane	0.4	0.4	0.5
3-Methylpentane	-	-	0.3
n-Hexane	0.3	0.3	0.4
Methylcyclopentane	-	-	-
Benzene	0.8	1.2	1.0
Cyclohexane	-	-	-
2-Methylhexane	-	-	-
3-Methylhexane	0.3	0.1	0.2
2,2,4-Trimethylpentane	-	-	-
Toluene	1.7	2.0	1.7
n-Octane	-	-	-
Ethylbenzene	1.3	-	0.7
p & *m*-Xylene	2.5	0.7	1.2
o-Xylene	1.1	1.0	0.3
Total Identified HC	20.7	17.4	22.2
TOTAL NMHC	45.7	36.9	29.0
% Paraffins	63	71	76
% Olefins	1	-	1
% Aromatics	36	28	22

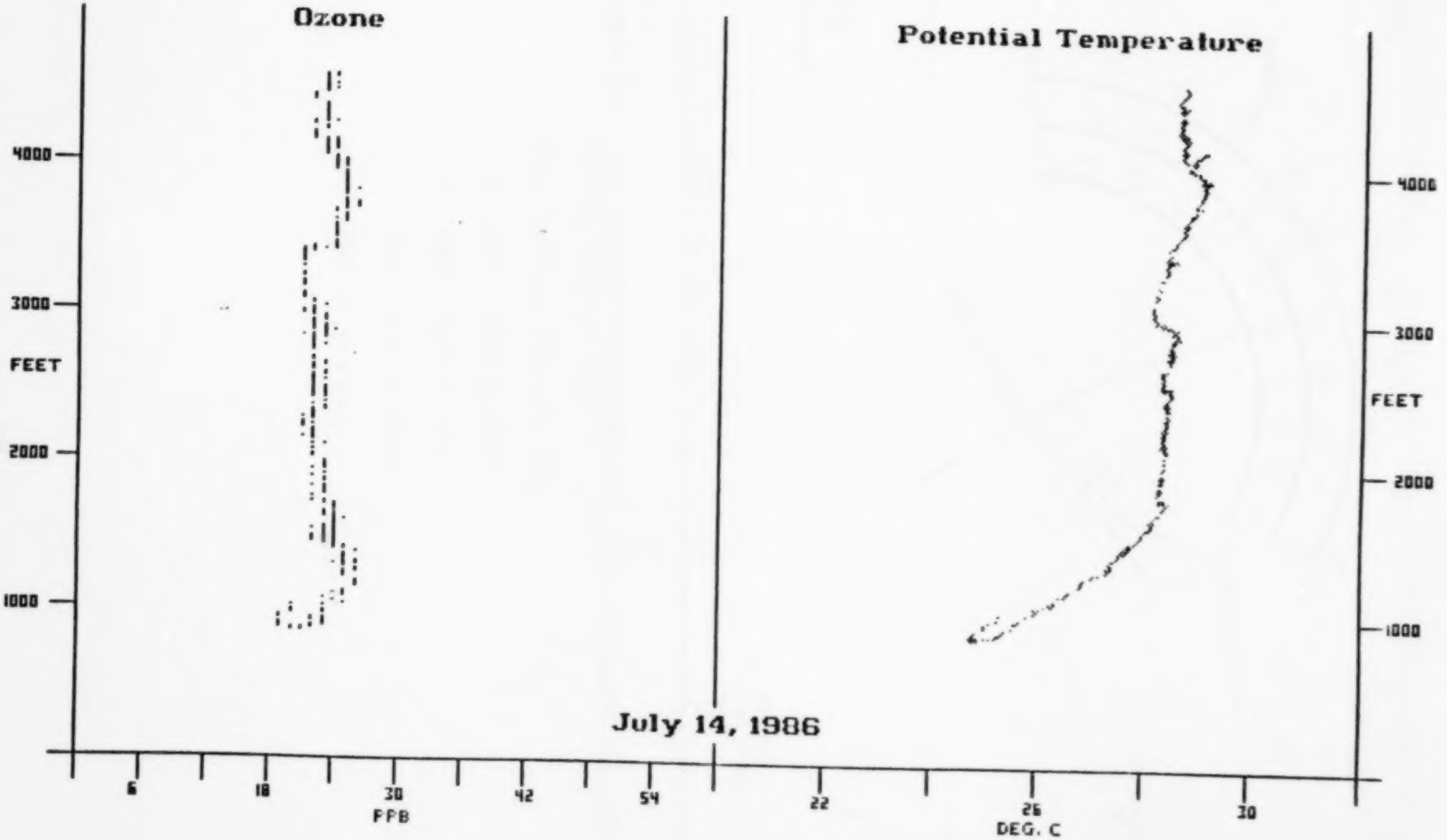
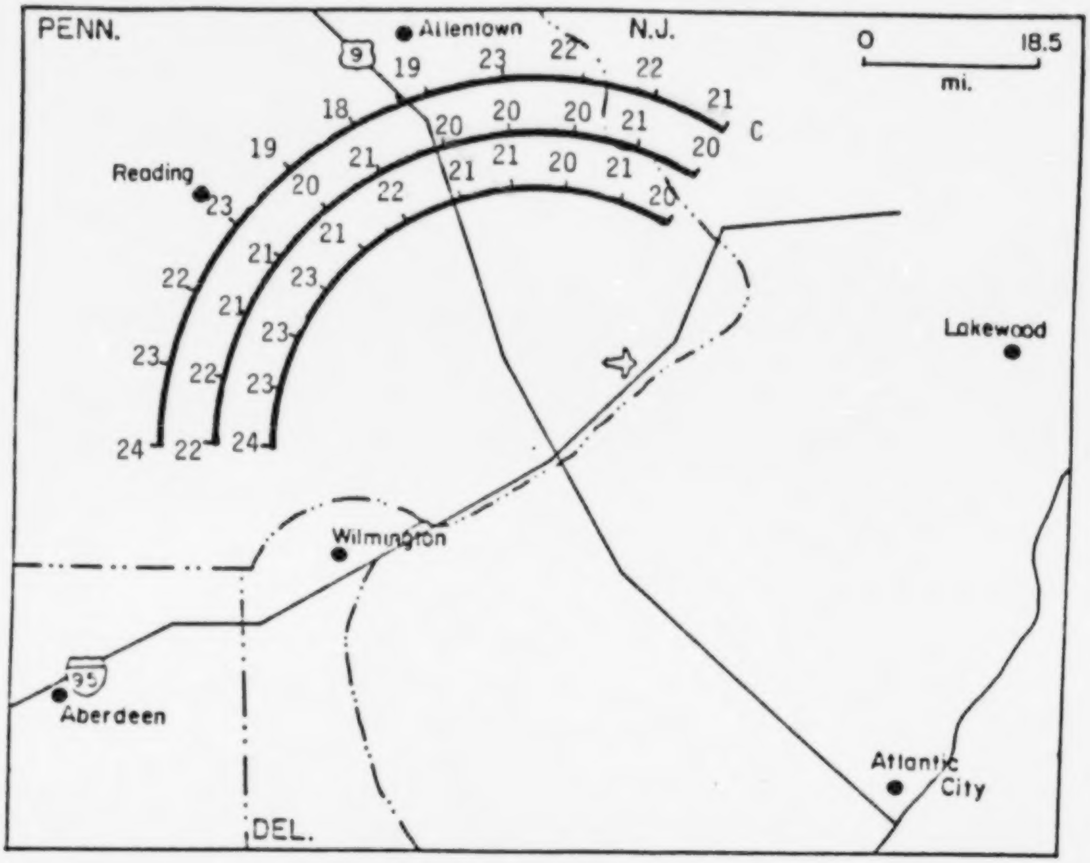


Figure E-8. Potential temperature and ozone changes with altitude on July 14, 1986.


PENN.
Allentown
N.J.
0
18.5
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C
Reading
Lakewood
Wilmington
95
Aberdeen
Atlantic City
DEL.
19 23 22 22 21
18 20 20 20 21 20
19 21 21 21 20 21 20
23 20 22
22 21 21 23
23 21 23 22 23
24 22 24

Figure E-9. July 15, 1986 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude (AGL)

A: 0525 - 0550 at 2500'

B: 0558 - 0627 at 3500'

C: 0633 - 0701 at 2500'

Wind: 330° at 18 knots

July 15, 1986

Morning Mixing Level: <1000 feet

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (EDT)	O3 (ppb)	NO (ppb)	NOx (ppb)	Temp (C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/040		05:24:47	20	1	1	18.2			
A/028		05:27:16	21	1	1	18.2			
A/016		05:29:52	20	0	1	18.4			
A/004		05:32:29	21	0	1	18.2			
A/352		05:35:05	21	0	1	17.9			
A/340	2500	05:37:42	22	0	1	18.0	6.6		
A/328		05:40:18	21	0	1	18.2			
A/316		05:42:55	23	1	1	18.4			
A/304		05:45:31	23	1	1	18.2			
A/292		05:48:08	23	0	1	18.0			
A/280		05:50:37	24	1	0	18.1			
B/280		05:58:11	22	0	1	16.5			
B/292		06:00:58	22	1	1	17.0			
B/304		06:03:52	21	0	1	16.8			
B/316		06:06:47	21	0	1	16.8			
B/328		06:09:42	20	0	0	17.0			
B/340	3500	06:12:37	21	0	1	17.2	8.6	1.1	0.6
B/352		06:15:31	20	0	1	17.2			
B/004		06:18:26	20	0	0	17.3			
B/016		06:21:21	20	0	0	16.6			
B/028		06:24:15	21	0	0	16.4			
B/040		06:27:03	20	0	0	16.3			
C/040		06:32:43	21	1	1	19.4			
C/028		06:35:29	22	0	1	19.4			
C/016		06:38:23	22	0	1	20.1			
C/004		06:41:17	23	1	1	20.1			
C/352		06:44:11	19	0	1	19.0			
C/340	2500	06:47:06	18	0	1	19.5	7.7	1.4	0.5
C/328		06:50:00	19	0	1	19.3			
C/316		06:52:54	23	0	1	19.5			
C/304		06:55:48	22	1	1	19.5			
C/292		06:58:42	23	0	1	19.3			
C/280		07:01:29	24	0	1	19.2			

* See flight map for Arc; Radial from Philadelphia city centre.

Table E-5. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 15, 1986

Hydrocarbon	A/C Arc A 0525 - 0551 (EDT)	A/C Arc B 0558 - 0627 (EDT)	A/C Arc C 0632 - 0701 (EDT)
Ethane	2.0	1.8	1.8
Ethylene	-	0.6	0.2
Acetylene	0.1	0.2	0.1
Propane	0.4	0.3	0.5
Propene	-	-	-
i-Butane	0.1	0.1	0.1
n-Butane	0.2	0.2	0.3
i-Pentane	0.3	0.1	0.5
n-Pentane	0.1	-	0.2
Cyclopentane	-	-	-
Isoprene	-	-	-
2,3-Dimethylbutane	-	-	-
2-Methylpentane	-	-	-
3-Methylpentane	-	-	-
n-Hexane	-	-	-
Methylcyclopentane	-	-	-
Benzene	0.4	0.1	0.4
Cyclohexane	-	-	-
2-Methylhexane	-	-	-
3-Methylhexane	-	0.1	0.2
2,2,4-Trimethylpentane	-	-	-
Toluene	1.4	1.0	1.2
n-Octane	-	-	-
Ethylbenzene	0.4	0.7	0.4
p & *m*-Xylene	0.7	1.8	0.8
o-Xylene	0.5	1.6	1.0
Total Identified HC	6.6	8.6	7.7
TOTAL NMHC	9.9	14.2	18.3
% Paraffins	54	31	43
% Olefins	-	7	3
% Aromatics	45	60	53

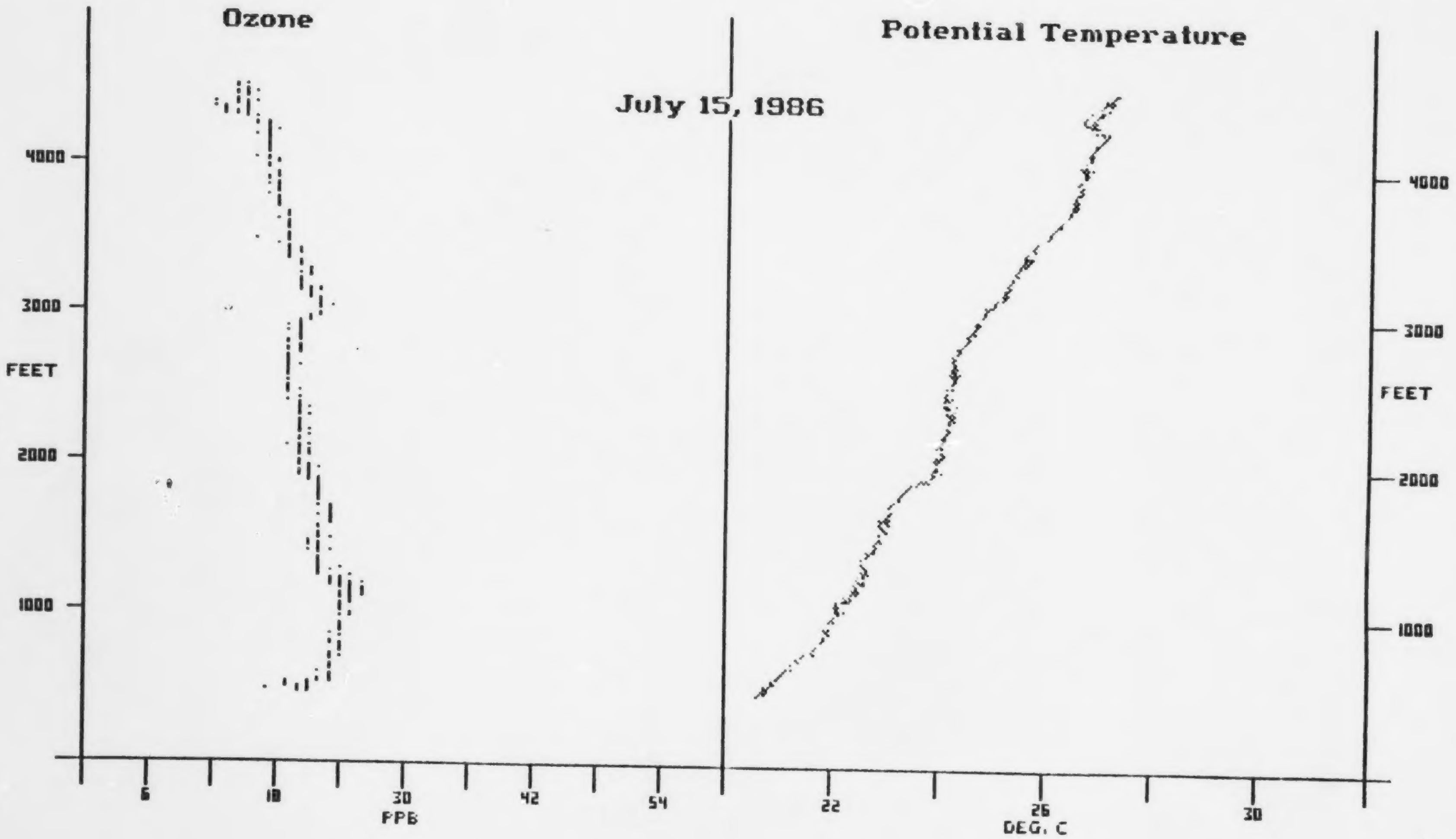
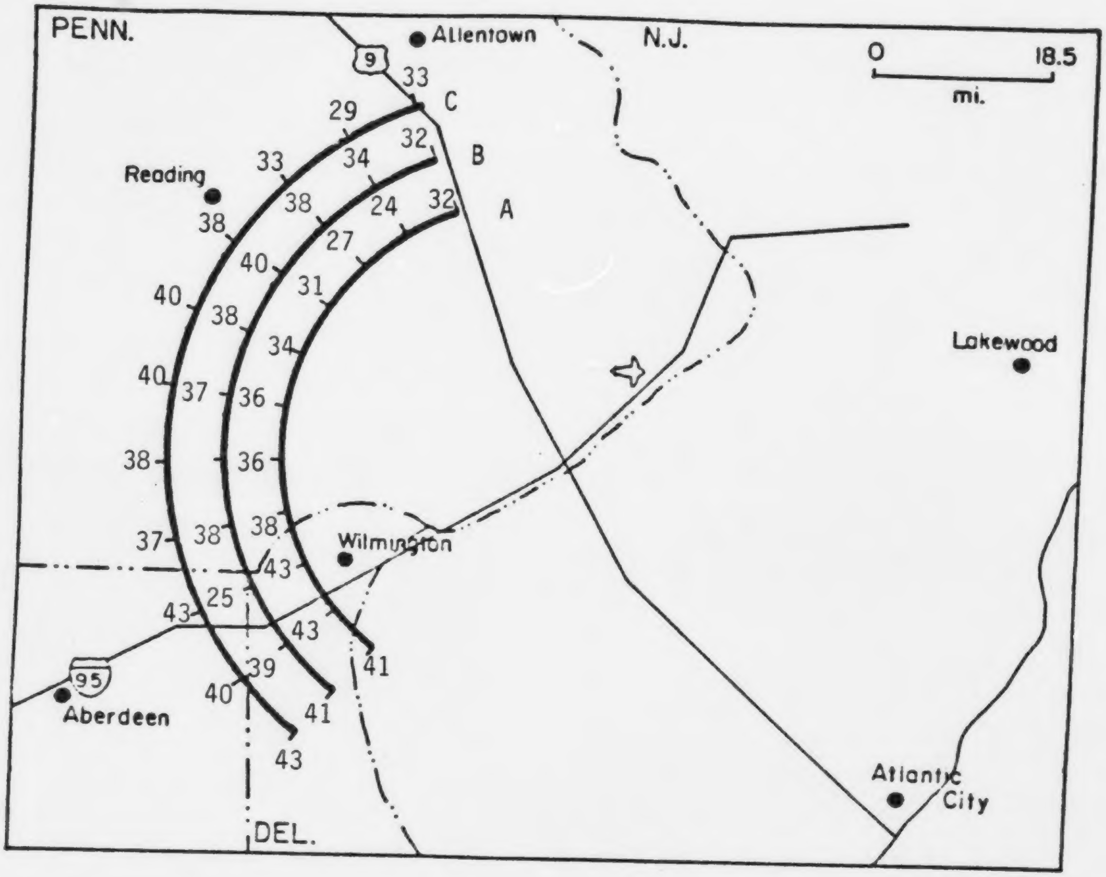


Figure E-10. Potential temperature and ozone changes with altitude on July 15, 1986.


PENN.
Allentown
N.J.
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18.5
mi.
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33
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29
32
B
33
34
Reading
38
24
32
A
38
27
40
31
40
38
34
Lakewood
40
37
36
38
36
38
38
37
38
Wilmington
43
43
25
43
95
39
41
40
Aberdeen
41
43
Atlantic City
DEL.

Figure E-11. July 16, 1986 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude (AGL)

A: 0537 - 0604 at 2000'

B: 0610 - 0638 at 3000'

C: 0642 - 0711 at 2000'

Wind: 290° at 8 knots

July 16, 1986

Morning Mixing Level: 900 feet

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (EDT)	O3 (ppb)	NO (ppb)	NOx (ppb)	Temp (C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/350	2000	05:36:49	32	2	2	22.6	19.4	3.4	1.5
A/338		05:39:23	24	2	5	22.6			
A/326		05:42:05	27	2	5	22.9			
A/314		05:44:48	31	2	2	23.3			
A/302		05:47:30	34	2	1	23.5			
A/290		05:50:12	36	2	2	23.6			
A/278		05:52:54	36	1	2	23.7			
A/266		05:55:36	38	3	3	23.8			
A/254		05:58:19	43	2	3	23.8			
A/242		06:01:01	43	2	4	23.3			
A/230		06:03:36	41	2	4	23.3			
B/230	3000	06:10:22	41	3	1	22.1		3.9	1.3
B/242		06:13:03	39	2	3	22.1			
B/254		06:15:52	25	2	10	22.0			
B/266		06:18:42	38	2	2	21.8			
B/278		06:21:31		2	2	21.6			
B/290		06:24:20	37	2	2	21.3			
B/302		06:27:09	38	2	3	20.8			
B/314		06:29:58	40	1	2	20.6			
B/326		06:32:48	38	2	4	20.4			
B/338		06:35:37	34	2	3	20.4			
B/350		06:38:19	32	3	2	20.4			
C/350	2000	06:42:03	33	2	3	22.8	11.6	3.4	1.4
C/338		06:44:50	29	2	5	23.3			
C/326		06:47:46	33	1	3	23.8			
C/314		06:50:41	38			24.3			
C/302		06:53:37	40	1	2				
C/290		06:56:32	40	1	3				
C/278		06:59:27	38	2	1	24.5			
C/266		07:02:23	37	3	2	24.7			
C/254		07:05:18	43	2	2	24.9			
C/242		07:08:14	40	1	3	24.8			
C/230		07:11:02	43	2	3	24.9			

* See flight map for Arc; Radial from Phildelphia city centre.

Table E-6. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 16, 1986

Hydrocarbon	A/C Arc A 0537 - 0604 (EDT)	A/C Arc B 0610 - 0638 (EDT)	A/C Arc C 0642 - 0711 (EDT)
Ethane	3.9	7.2	2.8
Ethylene	0.5	0.3	0.2
Acetylene	0.3	0.4	0.2
Propane	0.9	1.1	1.2
Propene	-	0.1	0.1
i-Butane	0.4	0.4	0.3
n-Butane	0.7	0.9	0.7
i-Pentane	0.8	0.5	0.7
n-Pentane	0.2	0.2	0.4
Cyclopentane	-	-	-
Isoprene	-	-	-
2,3-Dimethylbutane	-	-	-
2-Methylpentane	0.2	-	0.1
3-Methylpentane	-	-	-
n-Hexane	0.1	-	0.1
Methylcyclopentane	-	-	-
Benzene	0.8	0.2	0.7
Cyclohexane	-	-	-
2-Methylhexane	-	-	-
3-Methylhexane	0.9	-	0.7
2,2,4-Trimethylpentane	-	-	-
Toluene	1.6	0.8	1.5
n-Octane	-	-	-
Ethylbenzene	1.1	*	0.3
p & *m*-Xylene	4.4	*	0.8
o-Xylene	2.6	*	0.8
Total Identified HC	19.4	*	11.6
TOTAL NMHC	32.4	*	15.0
% Paraffins	41	*	61
% Olefins	3	*	2
% Aromatics	54	*	35

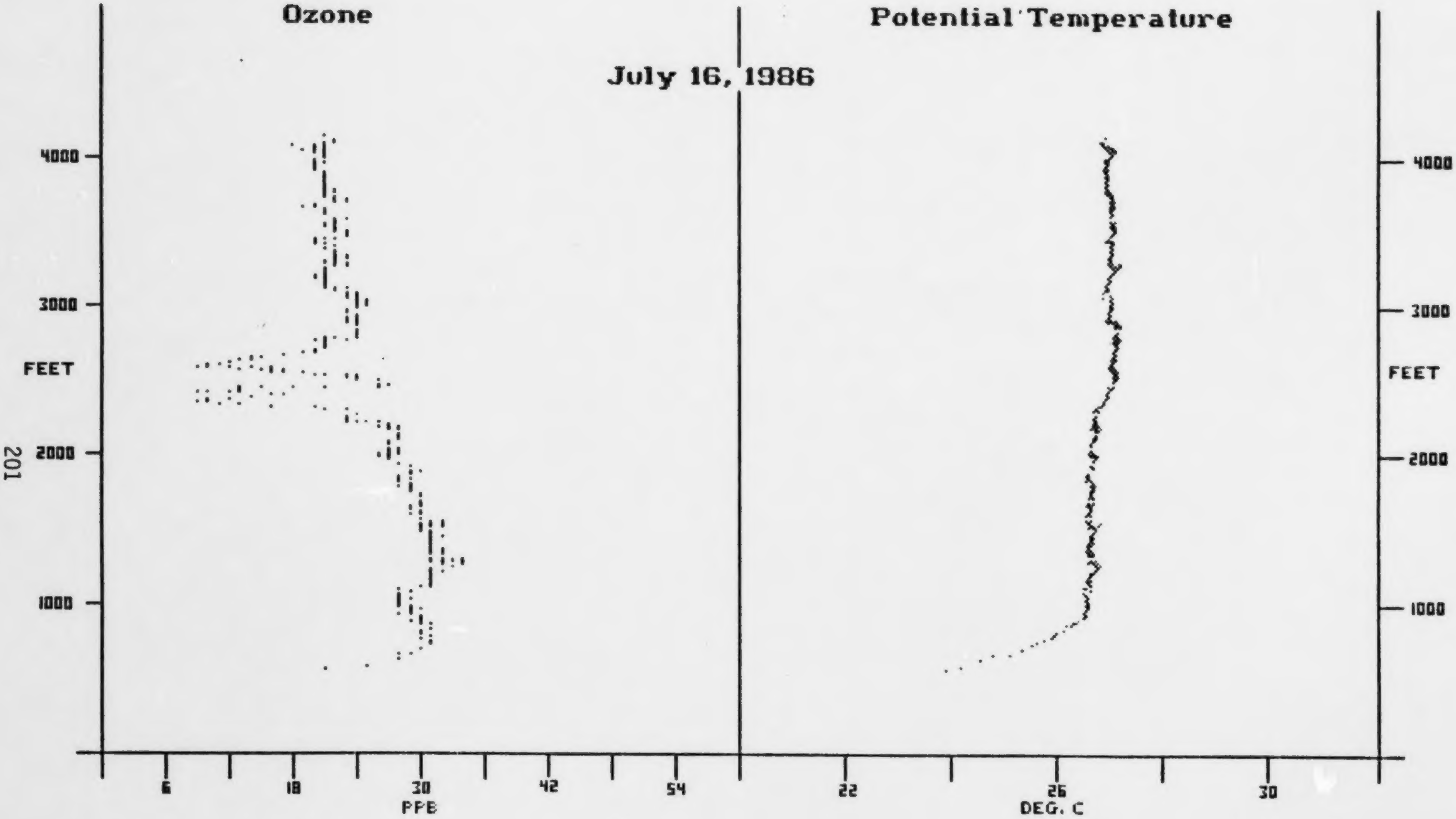
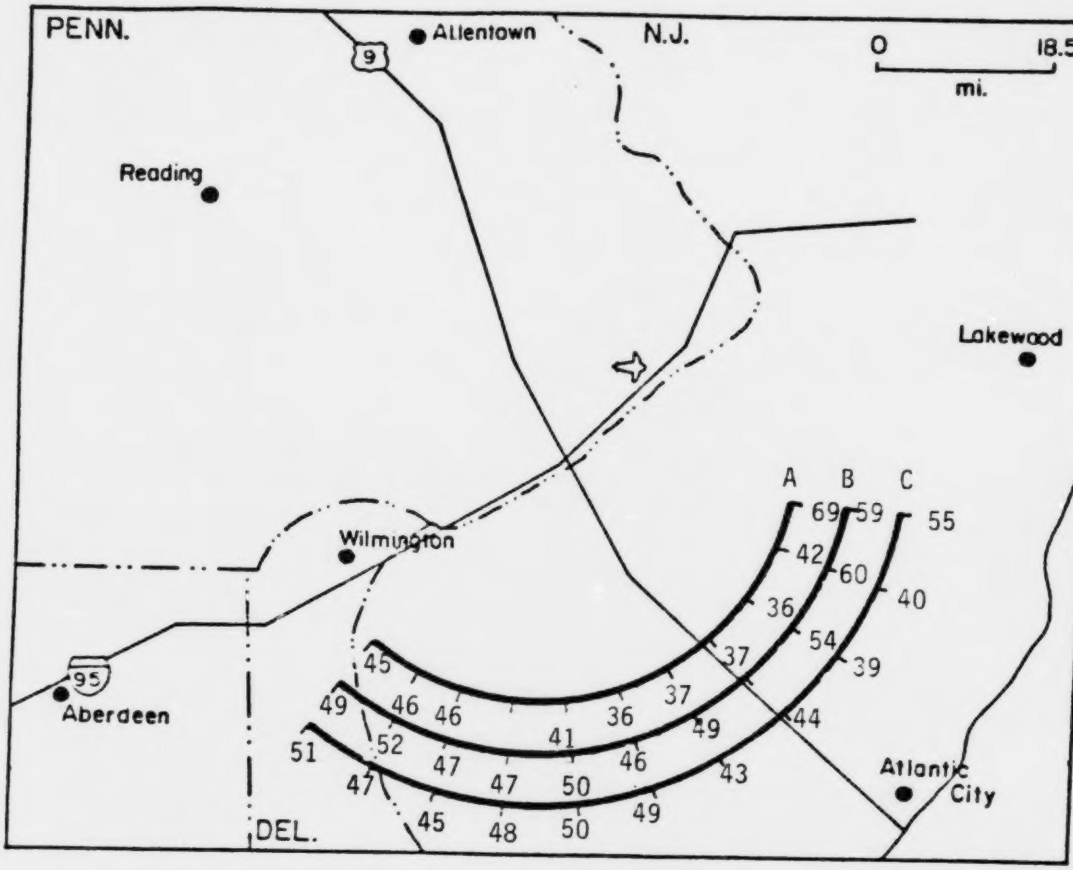


Figure E-12. Potential temperature and ozone changes with altitude on July 16, 1986.


PENN.
Allentown
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9
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mi.
Reading
Lakewood
Wilmington
95
Aberdeen
DEL.
Atlantic City
A
B
C
69
59
55
42
60
40
36
54
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37
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49
49
41
52
47
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43
51
47
45
48
50
49

Figure E-13. July 24, 1986 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude (AGL)

A: 0559 - 0627 at 2500'

B: 0633 - 0701 at 3500'

C: 0706 - 0736 at 3500'

Wind: 160° at 8 knots

July 24, 1986

Morning Mixing Level: 1400 feet

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (EDT)	O3 (ppb)	NO (ppb)	NOx (ppb)	Temp (C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/230	2500	05:59:03	45	3	1	23.6	8.0	0.9	<0.1
A/218		06:01:46	46	1	1	23.2			
A/206		06:04:37	46	2	2	23.2			
A/194		06:07:28		2	1	23.4			
A/182		06:10:19	41	2	2	23.2			
A/170		06:13:10	36	2	1	23.0			
A/158		06:16:01	37	1	2	23.2			
A/146		06:18:52	37	2	2	23.2			
A/134		06:21:43	36	2	2	23.5			
A/122		06:24:34	42	2	1	23.2			
A/110		06:27:18	69	1	2	22.7			
B/110	3500	06:32:44	59	2	2	21.2	7.6	1.3	<0.1
B/122		06:35:28	60	3	1	20.8			
B/134		06:38:20	54	2	3	21.5			
B/146		06:41:12		2	1	21.4			
B/158		06:44:04	49	1	1	21.6			
B/170		06:46:56	46	2	2	21.3			
B/182		06:49:48	50	1	2	21.6			
B/194		06:52:40	47	2	1	21.6			
B/206		06:55:32	47	2	2	21.6			
B/218		06:58:24	52	2	1	21.3			
B/230		07:01:09	49	1	2	21.3			
C/230	3500	07:05:39	51	3	1	22.8	5.7	0.7	<0.1
C/218		07:08:33	47	2	1	23.7			
C/206		07:11:35	45	1	1	24.4			
C/194		07:14:38	48	1	0	23.9			
C/182		07:17:40	50	2	2	23.8			
C/170		07:20:42	49	1	1	23.6			
C/158		07:23:44	43	2	2	24.0			
C/146		07:26:46	44	2	2	24.1			
C/134		07:29:49	39	1	1	23.9			
C/122		07:32:51	40	2	2	23.8			
C/110		07:35:46	55	1	2	23.5			

* See flight map for Arc; Radial from Philadelphia city centre.

Table E-7. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 24, 1986

Hydrocarbon	A/C Arc A 0559 - 0627 (EDT)	A/C Arc B 0633 - 0701 (EDT)	A/C Arc C 0706 - 0736 (EDT)
Ethane	3.1	2.5	2.0
Ethylene	0.3	-	-
Acetylene	0.3	0.2	0.4
Propane	0.7	0.7	0.5
Propene	-	-	-
i-Butane	0.2	0.1	0.2
n-Butane	0.3	0.4	0.4
i-Pentane	0.6	0.4	0.2
n-Pentane	0.1	0.1	0.1
Cyclopentane	-	-	-
Isoprene	-	-	-
2,3-Dimethylbutane	-	-	-
2-Methylpentane	-	-	-
3-Methylpentane	-	-	-
n-Hexane	-	-	-
Methylcyclopentane	-	-	-
Benzene	0.4	0.6	0.5
Cyclohexane	-	-	-
2-Methylhexane	-	-	-
3-Methylhexane	0.4	0.3	-
2,2,4-Trimethylpentane	-	-	-
Toluene	0.6	0.5	0.5
n-Octane	-	-	-
Ethylbenzene	-	0.3	0.1
p & *m*-Xylene	0.6	0.9	0.5
o-Xylene	0.4	0.6	0.3
Total Identified HC	8.0	7.6	5.7
TOTAL NMHC	8.5	15.8	12.4
% Paraffins	62	59	60
% Olefins	4	-	-
% Aromatics	30	38	33

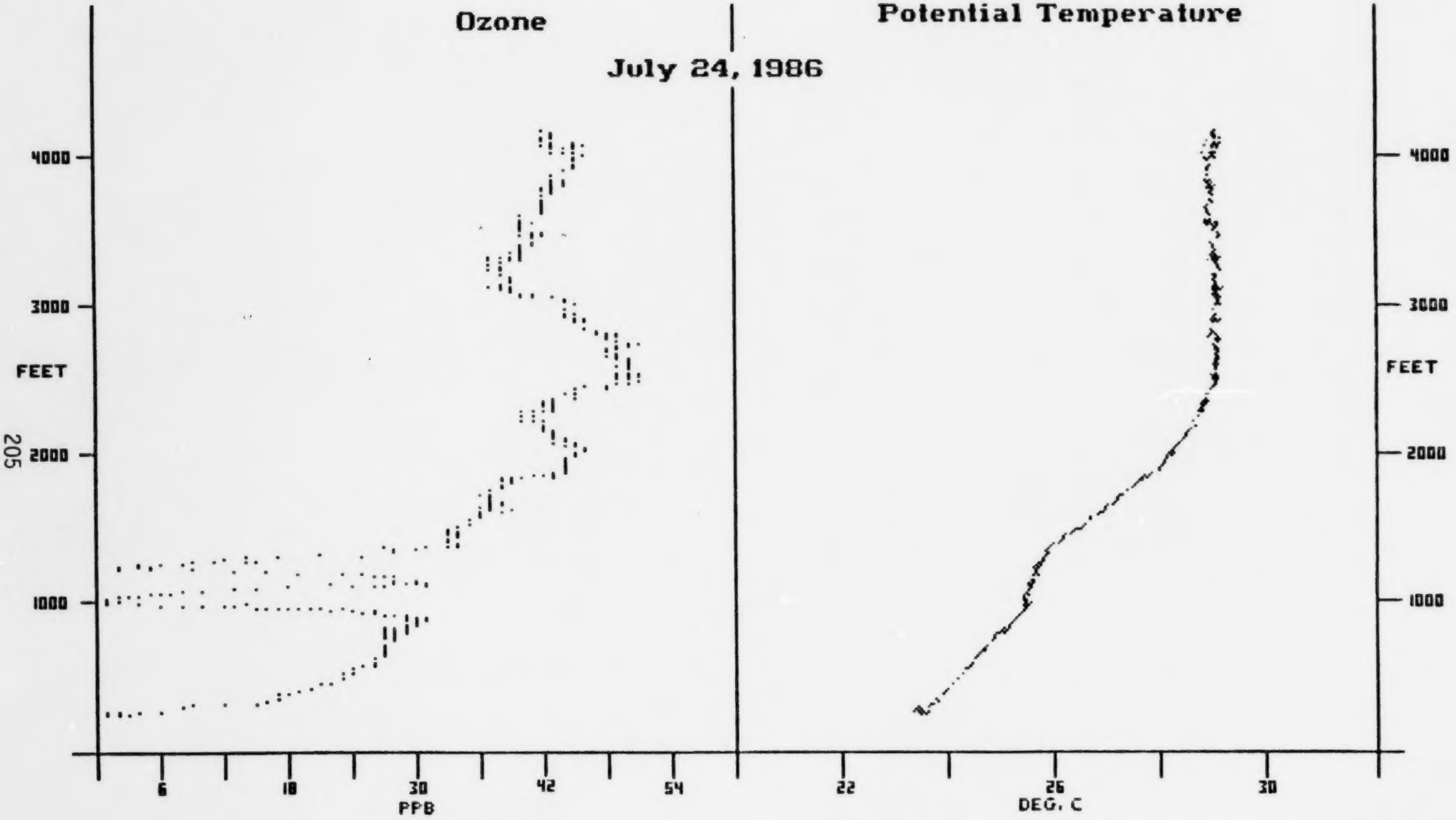


Figure E-14. Potential temperature and ozone changes with altitude on July 24, 1986.

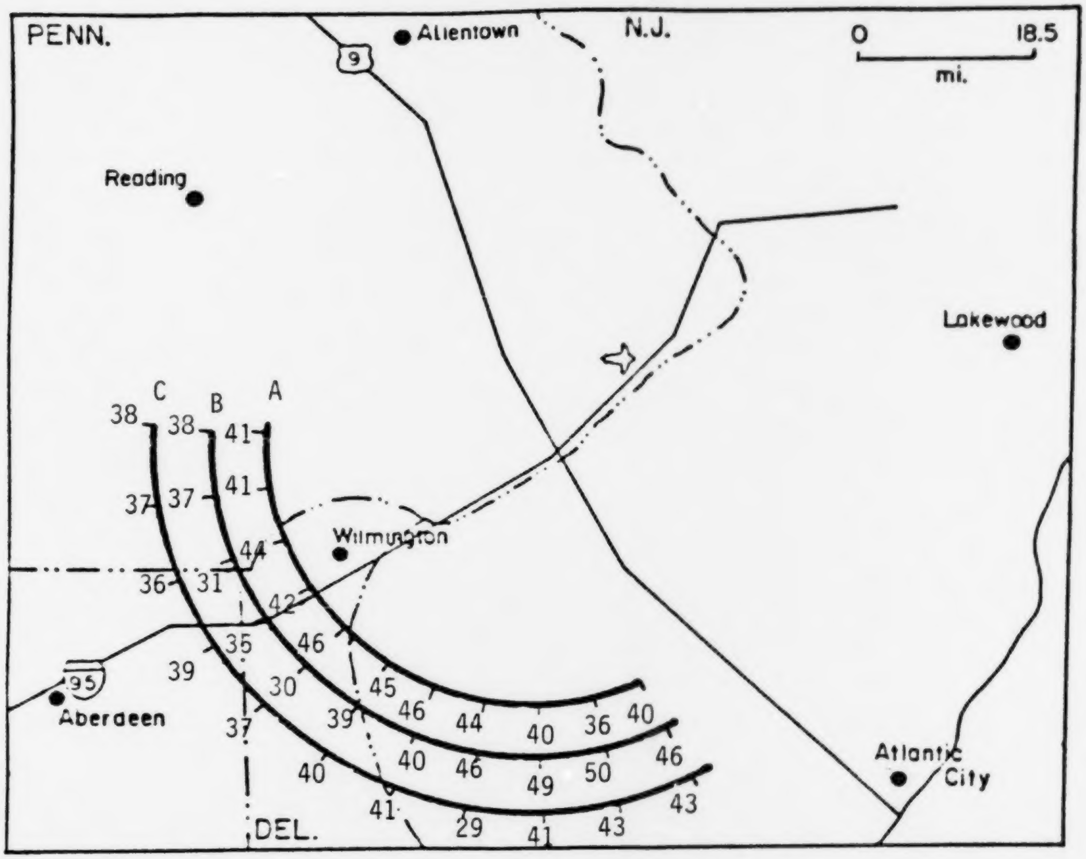

PENN.
Allentown
N.J.
0
18.5
mi.
9
Reading
Lakewood
C
B
A
38
38
41
37
37
41
Wilmington
44
36
31
42
46
35
39
45
30
46
95
39
44
40
36
40
Aberdeen
37
40
46
50
46
40
46
49
Atlantic City
43
41
29
41
43
DEL.

Figure E-15. July 25, 1986 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude (AGL)

A: 0548 - 0616 at 2000'

B: 0621 - 0649 at ~3000' (variable)

C: 0653 - 0725 at ~2000' (variable)

Wind: 210° at 15 knots

July 25, 1986

Morning Mixing Level: 1000 feet

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (EDT)	O3 (ppb)	NO (ppb)	NOx (ppb)	Temp (C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/280	2000	05:47:41	41	0	1	21.7	6.9	0.4	<0.1
A/268		05:50:26	41	0	1	22.0			
A/256		05:53:18	44	0	1	21.8			
A/244		05:56:11	42	0	1	22.2			
A/232		05:59:03	46	0	2	22.3			
A/220		06:01:56	45	0	2	22.4			
A/208		06:04:48	46	0	2	22.4			
A/196		06:07:41	44	1	2	22.0			
A/184		06:10:33	40	0	1	22.9			
A/172		06:13:26	36	1	1	21.7			
A/160		06:16:11	40	0	2	22.7			
B/160	VARIABLE	06:21:10	46	1	1	23.5	5.0	0.5	<0.1
B/172		06:23:49	50	0	2	22.7			
B/184		06:26:36	49	0	1	22.2			
B/196		06:29:22	46	0	1	21.9			
B/208		06:32:09	40	0	2	21.6			
B/220		06:34:56	34	0	2	21.4			
B/232		06:37:43	30	0	2	21.2			
B/244		06:40:30	35	1	1	20.3			
B/256		06:43:16	31	1	2	21.8			
B/268		06:46:03	37	1	1	22.2			
B/280		06:48:43	38	0	2	22.1			
C/280	VARIABLE	06:52:55	38	0	2	22.5	44.7	0.5	<0.1
C/268		06:55:59	37	0	1	23.2			
C/256		06:59:11	36	0	1	23.0			
C/244		07:02:22	39	0	2	23.4			
C/232		07:05:34	37	0	2	23.6			
C/220		07:08:46	40	0	2	23.7			
C/208		07:11:58	41			24.2			
C/196		07:15:10	29	0	1	22.2			
C/184		07:18:21	41	0	2	23.0			
C/172		07:21:33	43	0	2	22.6			
C/160		07:24:38	43	1	1	22.8			

* See flight map for Arcs; Radial from Philadelphia city centre.

Table E-8. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 25, 1986

Hydrocarbon	A/C Arc A 0548 - 0616 (EDT)	A/C Arc B 0621 - 0649 (EDT)	A/C Arc C 0653 - 0725 (EDT)
Ethane	2.4	1.9	2.3
Ethylene	0.5	-	4.9
Acetylene	0.3	0.1	0.9
Propane	0.8	0.4	1.7
Propene	-	-	0.3
i-Butane	0.2	0.1	1.3
n-Butane	0.3	0.2	4.4
i-Pentane	0.1	-	5.3
n-Pentane	-	-	1.4
Cyclopentane	-	-	-
Isoprene	-	-	1.2
2,3-Dimethylbutane	-	-	1.0
2-Methylpentane	-	-	1.1
3-Methylpentane	-	-	0.7
n-Hexane	-	-	0.6
Methylcyclopentane	-	-	0.4
Benzene	0.4	0.3	1.2
Cyclohexane	-	-	-
2-Methylhexane	-	-	1.3
3-Methylhexane	0.2	0.1	0.8
2,2,4-Trimethylpentane	-	-	4.1
Toluene	0.5	0.5	5.2
n-Octane	-	-	0.4
Ethylbenzene	0.2	-	0.8
p & *m*-Xylene	0.6	0.7	1.7
o-Xylene	0.4	0.7	1.7
Total Identified HC	6.9	5.0	44.7
TOTAL NMHC	9.1	22.9	51.0
% Paraffins	56	52	60
% Olefins	7	-	14
% Aromatics	30	46	24

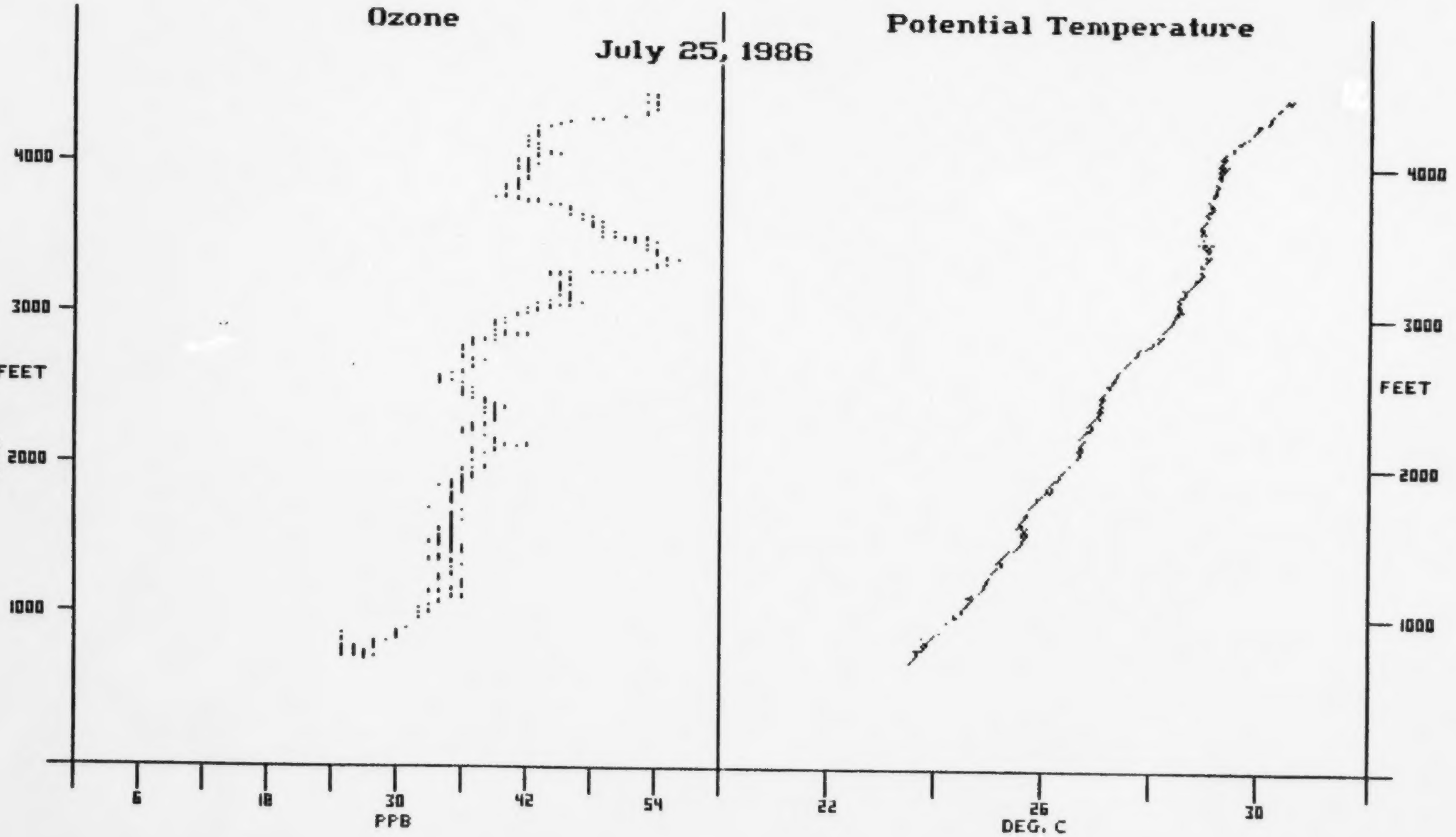


Figure E-16. Potential temperature and ozone changes with altitude on July 25, 1986.

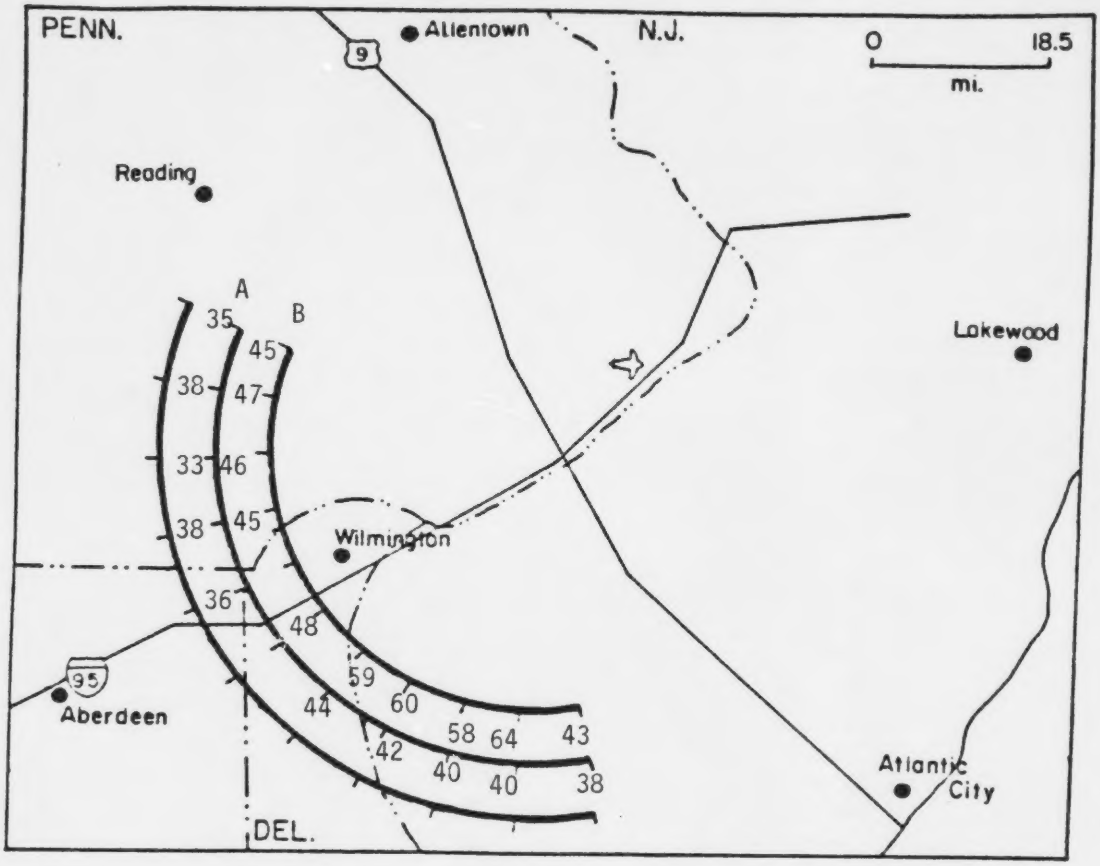

PENN.
Allentown
N.J.
0
18.5
mi.
9
Reading
A
B
35
45
38
47
33
46
38
45
Wilmington
36
48
59
60
44
58
64
43
42
40
40
38
95
Aberdeen
DEL.
Lakewood
Atlantic City

Figure E-17. July 27, 1986 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude (AGL)

A: 0608 - 0634 at 2000'

B: 0639 - 0707 at 3000'

Wind: 230° at 8 knots

July 27, 1986

Morning Mixing Level: 900 feet

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (EDT)	O3 (ppb)	NO (ppb)	NOx (ppb)	Temp (C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/180	2000	06:07:29	38	2	2	24.2	16.4	4.3	1.1
A/192		06:10:03	40	2	3	24.7			
A/204		06:12:44	40	2	3	25.0			
A/216		06:15:26	42	2	1	24.3			
A/228		06:18:07	44	1	1	24.2			
A/240		06:20:49		0	2	24.1			
A/252		06:23:30	36	1	5	23.5			
A/264		06:26:12	38	1	4	23.4			
A/276		06:28:53	33	2	4	22.9			
A/288		06:31:35	38	2	5	23.5			
A/300		06:34:09	35	1	5	23.2			
B/300	3000	06:39:29	45	1	3	22.1	51.4	4.5	1.2
B/288		06:42:09	47	1	3	21.8			
B/276		06:44:56	46	1	2	21.7			
B/264		06:47:44	45	1	2	22.2			
B/252		06:50:31		1	2	22.2			
B/240		06:53:19	48	1	1	22.8			
B/228		06:56:07	59	0	2	22.1			
B/216		06:58:54	60	1	3	22.0			
B/204		07:01:42	58	2	3	22.6			
B/192		07:04:29	64	1	3	22.7			
B/180		07:07:10	43	1	3	22.2			

* See flight map for arcs; Radials from Philadelphia city centre.

Table E-9. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 27, 1986

Hydrocarbon	A/C Arc A 0607 - 0634 (EDT)	A/C Arc B 0639 - 0707 (EDT)
Ethane	4.2	4.2
Ethylene	0.2	6.9
Acetylene	0.4	1.1
Propane	2.1	2.6
Propene	-	0.3
i-Butane	0.3	1.7
n-Butane	1.6	5.2
i-Pentane	1.1	5.7
n-Pentane	0.6	2.3
Cyclopentane	-	0.2
Isoprene	-	1.7
2,3-Dimethylbutane	-	0.4
2-Methylpentane	0.3	1.4
3-Methylpentane	-	1.1
n-Hexane	0.1	0.9
Methylcyclopentane	-	0.8
Benzene	0.7	1.8
Cyclohexane	-	-
2-Methylhexane	-	1.5
3-Methylhexane	1.1	0.7
2,2,4-Trimethylpentane	-	0.8
Toluene	1.2	5.4
n-Octane	-	0.5
Ethylbenzene	-	1.0
p & *m*-Xylene	0.8	1.5
o-Xylene	1.7	1.7
Total Identified HC	16.4	51.4
TOTAL NMHC	47.1	58.9
% Paraffins	70	59
% Olefins	1	17
% Aromatics	27	22

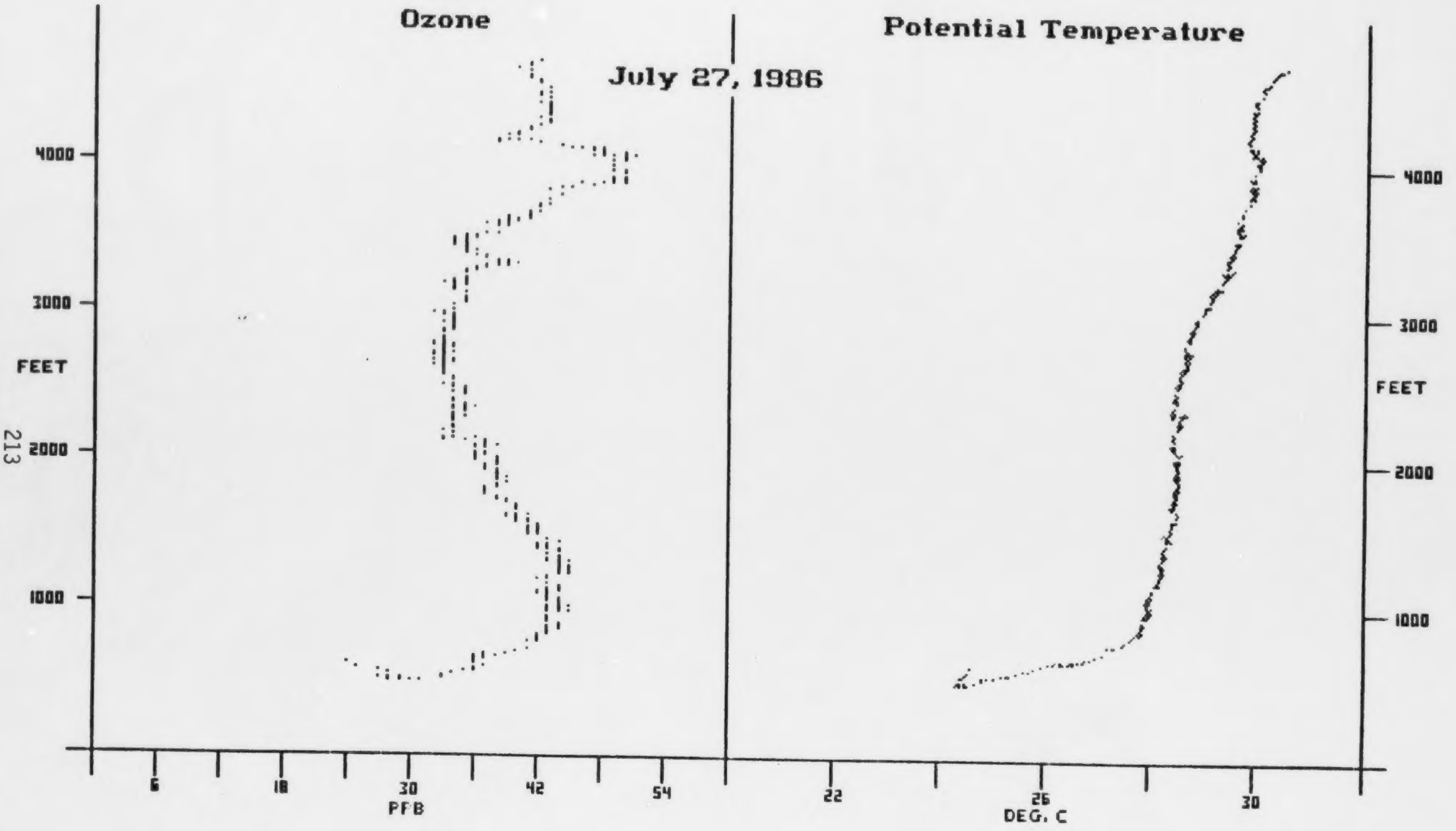


Figure E-18. Potential temperature and ozone changes with altitude on July 27, 1986.

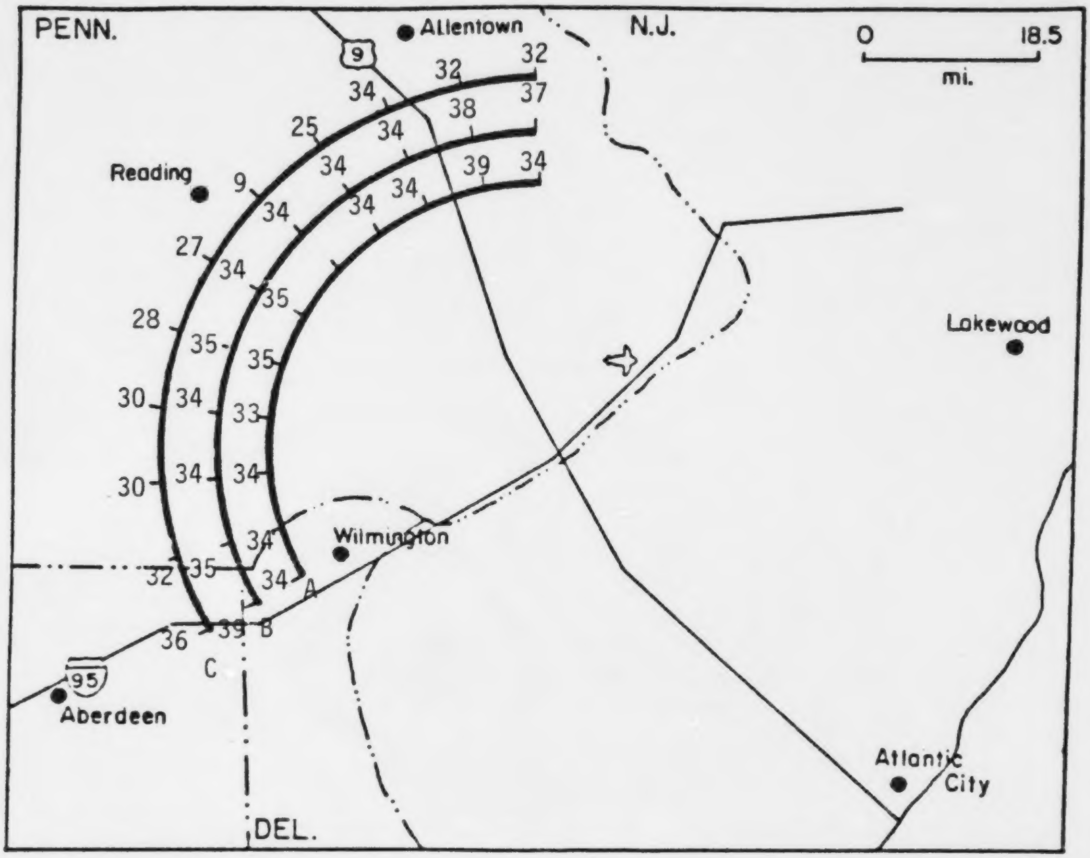

PENN.
N.J.
DEL.
Allentown
Reading
Wilmington
Lakewood
Aberdeen
Atlantic City
9
95
0
18.5
mi.
A
B
C
32
32
37
38
34
34
39
34
25
34
34
9
34
34
34
27
34
35
28
35
35
30
34
33
30
34
34
32
35
34
34
36
39

Figure E-19. July 30, 1986 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude (AGL)

A: 0612 - 0639 at 2000'

B: 0644 - 0713 at 3000'

C: 0721 - 0749 at 2000'

Wind: 300° at 9 knots

July 30, 1986

Morning Mixing Level: 1800 feet

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (EDT)	O3 (ppb)	NO (ppb)	NOx (ppb)	Temp (C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/010		06:11:49	34	1	2	20.7			
A/358		06:14:25	39	2	2	21.1			
A/346		06:17:09	34	1	2	20.9			
A/334		06:19:52	34	1	2	20.9			
A/322		06:22:36		1	2	20.9			
A/310	2000	06:25:20	35	2	3	21.0	12.2	1.1	0.7
A/298		06:28:04	35	0	2	20.7			
A/286		06:30:48	33	1	2	20.5			
A/274		06:33:31	34	1	2	20.8			
A/262		06:36:15	34	1	2	20.9			
A/250		06:38:52	34	1	3	21.1			
B/250		06:44:25	39	2	2	20.2			
B/262		06:47:13	35	0	2	20.2			
B/274		06:50:08	34	1	1	20.2			
B/286		06:53:04	34	1	2	19.9			
B/298		06:55:59	35	1	1	20.3			
B/310	3000	06:58:55	34	1	1	20.1	7.1	1.5	0.7
B/322		07:01:51	34	1	2	19.8			
B/334		07:04:46	34	0	2	20.1			
B/346		07:07:42	34	1	2	20.4			
B/358		07:10:37	38	1	3	20.5			
B/010		07:13:26	37	1	2	20.0			
C/010		07:21:01	32	1	3	21.0			
C/358		07:23:44	32	0	2	21.0			
C/346		07:26:36	34	1	2	21.7			
C/334		07:29:27	25	1	5	20.3			
C/322		07:32:19	9	7	15	20.3			
C/310	2000	07:35:10	27			20.1	16.7	0.9	0.4
C/298		07:38:01	28	1	3	20.3			
C/286		07:40:53	30	1	2	20.8			
C/274		07:43:44	30	1	1	21.3			
C/262		07:46:36	32	1	2	21.6			
C/250		07:49:20	36	1	2	22.3			

* See flight map for Arcs; Radials from Philadelphia city centre.

Table E-10. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 30, 1986

Hydrocarbon	A/C Arc A 0612 - 0639 (EDT)	A/C Arc B 0644 - 0713 (EDT)	A/C Arc C 0721 - 0749 (EDT)
Ethane	3.9	2.7	5.8
Ethylene	-	0.2	0.4
Acetylene	0.3	0.2	0.3
Propane	2.3	1.2	3.3
Propene	-	-	-
i-Butane	0.5	0.2	0.7
n-Butane	1.5	0.7	1.5
i-Pentane	0.9	0.5	1.2
n-Pentane	0.5	0.3	0.8
Cyclopentane	-	-	-
Isoprene	-	-	-
2,3-Dimethylbutane	-	-	-
2-Methylpentane	0.1	-	0.3
3-Methylpentane	-	-	0.1
n-Hexane	0.1	-	0.2
Methylcyclopentane	-	-	-
Benzene	0.3	0.3	0.6
Cyclohexane	-	-	-
2-Methylhexane	-	-	-
3-Methylhexane	-	0.1	-
2,2,4-Trimethylpentane	-	-	-
Toluene	0.8	0.5	0.7
n-Octane	-	-	-
Ethylbenzene	-	-	0.1
p & *m*-Xylene	0.5	0.2	0.6
o-Xylene	0.5	-	0.1
Total Identified HC	12.2	7.1	16.7
TOTAL NMHC	14.7	10.0	17.3
% Paraffins	81	78	83
% Olefins	-	3	2
% Aromatics	17	16	13

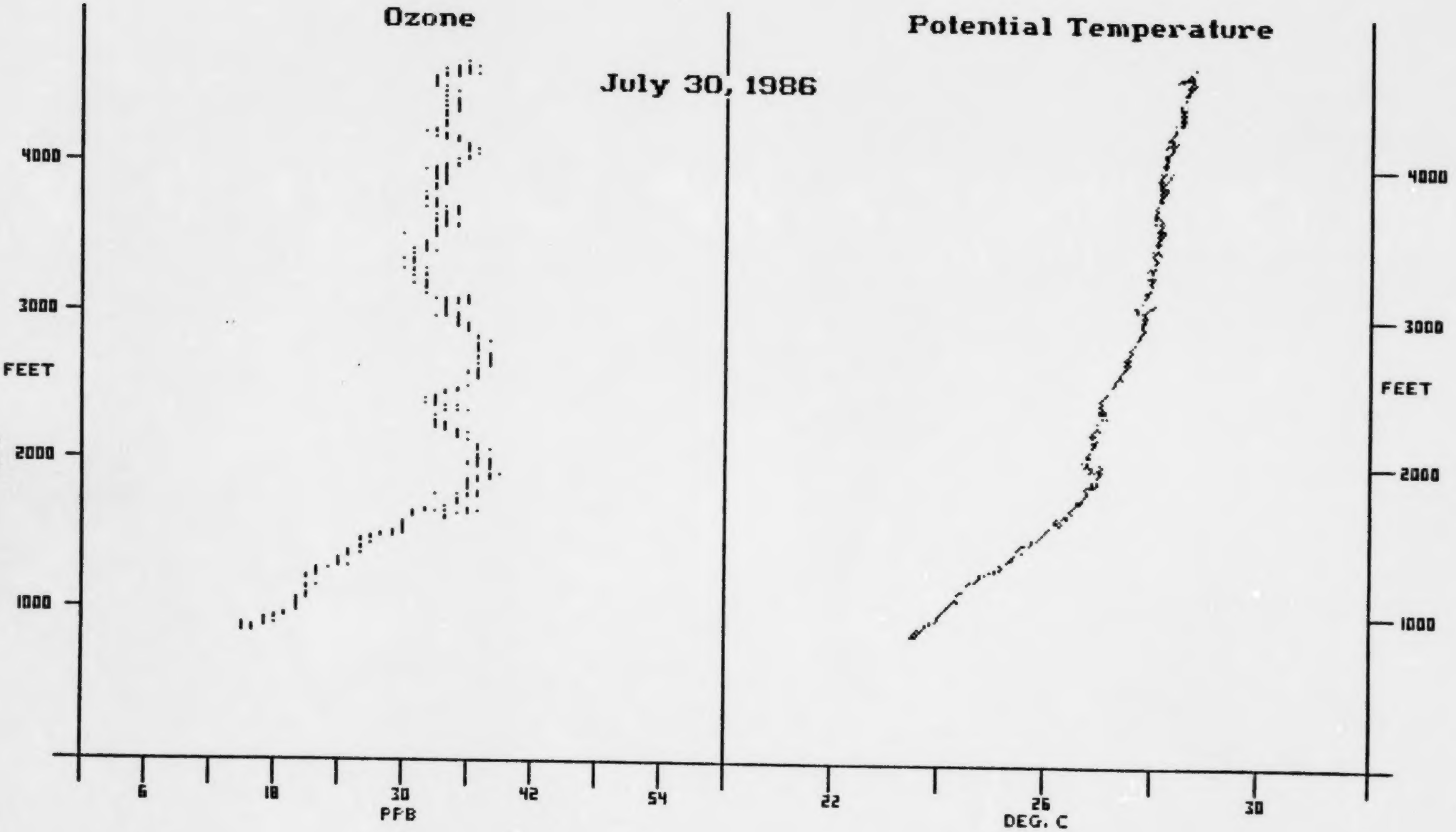


Figure E-20. Potential temperature and ozone changes with altitude on July 30, 1986.

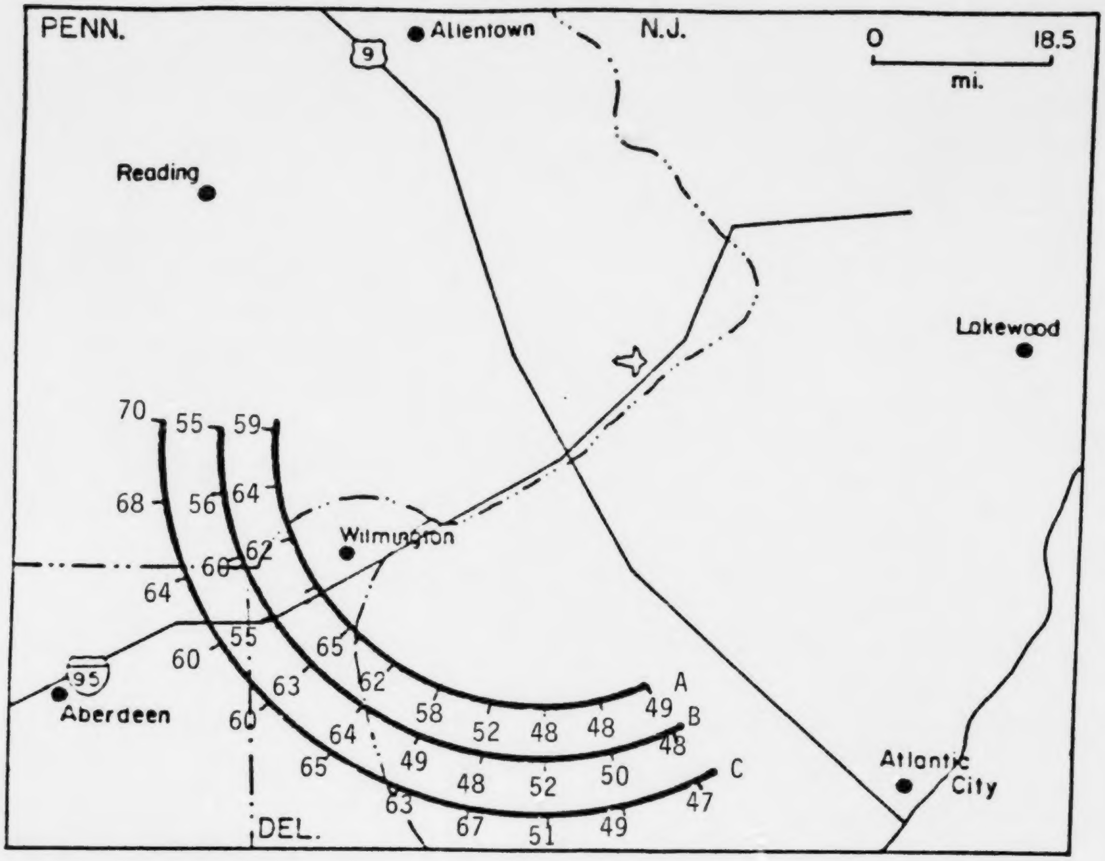

PENN.
Allentown
9
N.J.
0
18.5
mi.
Reading
Lakewood
Wilmington
95
Aberdeen
DEL.
Atlantic City
A
B
C
70
55
59
68
56
64
60
62
64
55
60
65
63
62
60
58
52
48
48
49
64
49
48
52
50
48
65
63
67
51
49
47

Figure E-21. August 6, 1986 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude (AGL).

A: 0555 - 0622 at 3000'

B: 0628 - 0656 at 3500'

C: 0701 - 0730 at 3000'

Wind: 210° at 13 knots

August 6,1986

Morning Mixing Level: Unknown

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (EDT)	O3 (ppb)	NO (ppb)	NOx (ppb)	Temp (C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/280	3000	05:55:09	59	0	1	21.3	7.8	0.9	0.9
A/268		05:57:46	64	0	1	20.7			
A/256		06:00:30	62	0	-1	20.9			
A/244		06:03:15		0	0	20.6			
A/232		06:06:00	65	0	1	20.8			
A/220		06:08:45	62	0	0	20.8			
A/208		06:11:29	58	0	0	21.6			
A/196		06:14:14	52	0	0	21.9			
A/184		06:16:59	48	0	0	22.2			
A/172		06:19:43	48	0	1	21.8			
A/160		06:22:21	49	0	1	21.8			
B/160	3500	06:28:29	48	0	0	21.4	9.6	1.3	0.7
B/172		06:31:06	50	0	1	20.6			
B/184		06:33:52	52	0	0	21.6			
B/196		06:36:37	48	0	0	21.5			
B/208		06:39:22	49	0	1	21.6			
B/220		06:42:08	64	0	1	20.8			
B/232		06:44:53	63	0	1	20.9			
B/244		06:47:38	55	0	0	20.6			
B/256		06:50:23	60	0	1	21.4			
B/268		06:53:09	56	0	1	20.9			
B/280		06:55:47	55	0	1	21.0			
C/280	3000	07:00:42	70	0	1	22.1	11.1	1.8	0.9
C/268		07:03:33	68	0	1	22.0			
C/256		07:06:32	64	0	1	22.5			
C/244		07:09:31	60	0	0	22.3			
C/232		07:12:30	60			22.4			
C/220		07:15:29	65	0	0	22.2			
C/208		07:18:28	63	0	0	22.2			
C/196		07:21:27	67	0	0	22.2			
C/184		07:24:26	51	0	-1	22.5			
C/172		07:27:25	49	0	1	22.9			
C/160		07:30:17	47	0	-1				

* See flight map for Arcs; Radials from Philadelphia city centre.

Table E-11. Hydrocarbon Concentrations (ppbC) in Samples Collected on August 6, 1986

Hydrocarbon	A/C Arc A 0555 - 0622 (EDT)	A/C Arc B 0628 - 0656 (EDT)	A/C Arc C 0701 - 0730 (EDT)
Ethane	3.6	4.7	4.9
Ethylene	-	-	0.2
Acetylene	0.5	0.5	0.4
Propane	1.3	1.3	1.7
Propene	-	-	-
i-Butane	0.4	0.3	0.3
n-Butane	0.7	0.9	0.9
i-Pentane	0.3	0.5	0.5
n-Pentane	0.1	0.2	0.1
Cyclopentane	-	-	-
Isoprene	-	-	-
2,3-Dimethylbutane	-	-	-
2-Methylpentane	-	-	-
3-Methylpentane	-	-	-
n-Hexane	-	-	-
Methylcyclopentane	-	-	-
Benzene	0.5	0.6	0.7
Cyclohexane	-	-	-
2-Methylhexane	-	-	-
3-Methylhexane	0.2	0.5	0.4
2,2,4-Trimethylpentane	-	-	-
Toluene	0.1	0.1	0.3
n-Octane	-	-	-
Ethylbenzene	-	-	-
p & *m*-Xylene	-	-	-
o-Xylene	0.1	-	0.7
Total Identified HC	7.8	9.6	11.1
TOTAL NMHC	8.3	14.7	11.5
% Paraffins	85	88	79
% Olefins	-	-	2
% Aromatics	9	7	15

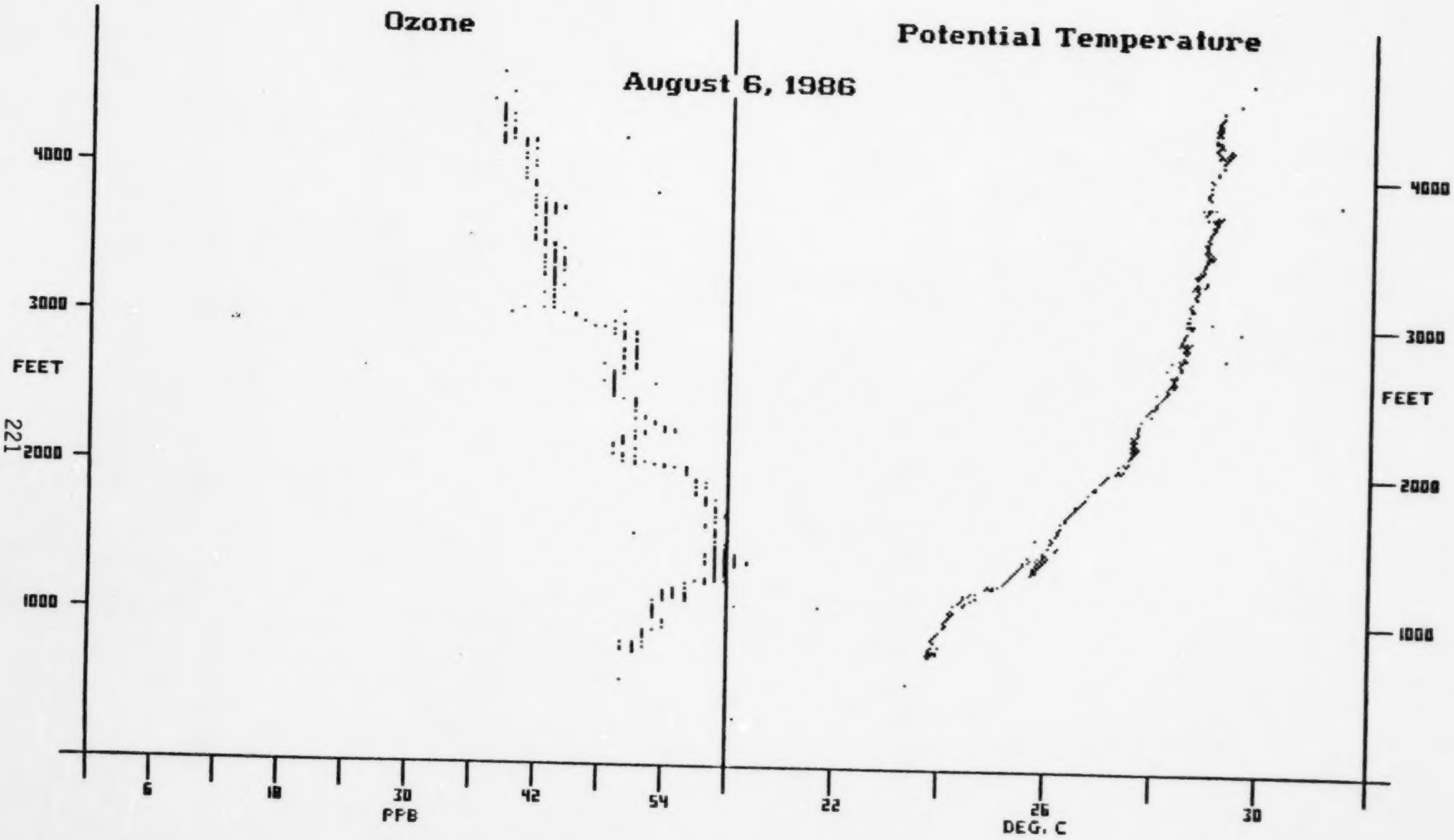


Figure E-22. Potential temperature and ozone changes with altitude on August 6, 1986.

APPENDIX F

Aircraft Flight Maps and Pollutant Measurement Data Obtained from New York City, New York

NEW YORK AIR QUALITY DATA

This section provides a tabulation of airborne data collected in the New York area during the period July 21 and August 14, 1986. For each sampling day, there is a flight map with ozone concentrations marked along the route, a tabulation of air quality data, a listing of individual hydrocarbon concentrations and a graphical summary of ozone, NO_x and temperature changes with altitude.

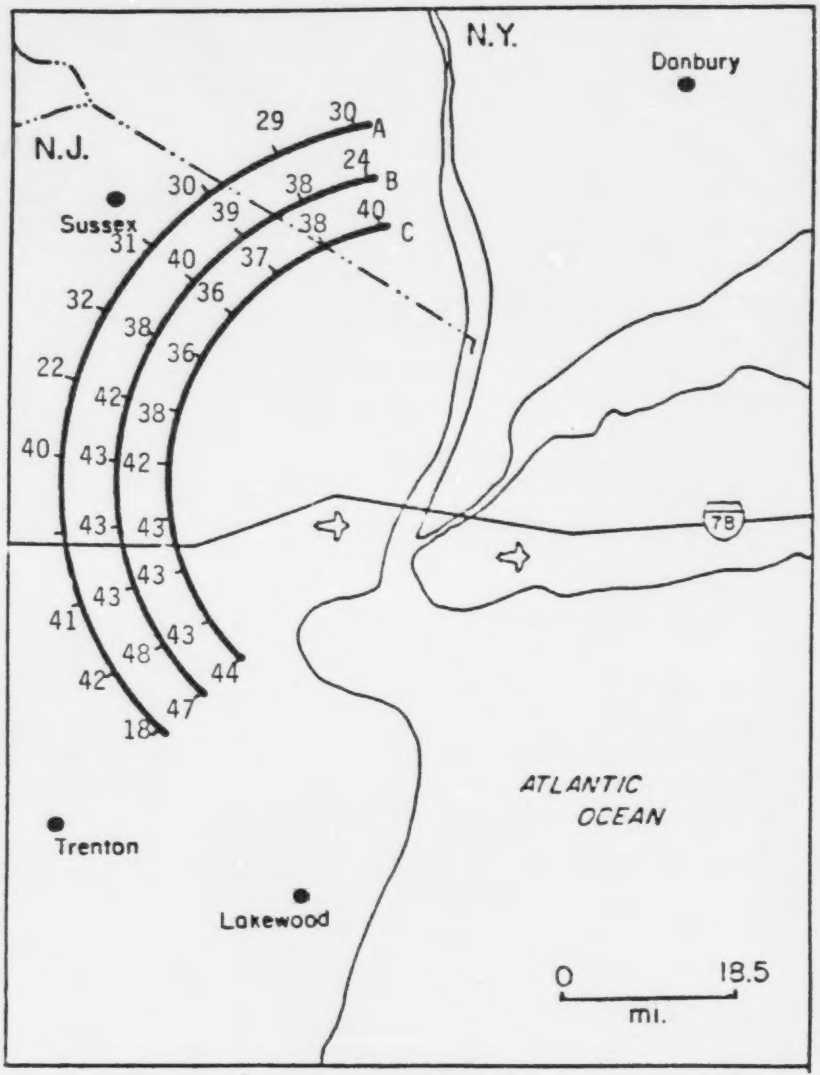
NOTES on Hydrocarbon Tables

* Means data not available

- Means concentration less than 0.1 ppbC

( ) Ethylene values in parentheses were calculated by multiplying the propane concentration by 0.18. This was necessary in cases of obvious ethylene contamination due to the presence of a chemiluminescent ozone analyzer. The ethylene-propane ratio was derived from airborne samples that were free of contamination problems.

TNMHC is the sum of all gas chromatographic peaks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ATLANTIC OCEAN
Trenton
Lakewood
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mi.

Figure F-1. July 21, 1986 flight path with ozone concentrations (ppb) - marked along the route.

Time (EDT) and Altitude (AGL)

A: 0555 - 0627 at 2500'

B: 0632 - 0657 at 3500'

C: 0703 - 0735 at 2500'

Wind: 300° at 12 knots

July 21,1986

Morning Mixing Level: <1000 feet

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (EDT)	O3 (ppb)	NO (ppb)	NOx (ppb)	Temp (C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/240		05:55:16	18	1	2				
A/252		05:58:18	42	2	2				
A/264		06:01:29	41	1	1				
A/276		06:04:39		0	2				
A/288		06:07:50	40	0	3				
A/300	2500	06:11:00	22	1	1		23.4		
A/312		06:14:10	32	1	2				
A/324		06:17:21	31	1	3				
A/336		06:20:31	30	1	3				
A/348		06:23:42	29	1	2				
A/360		06:26:45	30	1	3				
B/360		06:31:35	24	1	2				
B/348		06:34:00	38	2	2				
B/336		06:36:32	39	1	2				
B/324		06:39:05	40	1	3				
B/312		06:41:37	38	1	2				
B/300	3500	06:44:10	42	0	3		13.7	<0.1	<0.1
B/288		06:46:43	43	0	3				
B/276		06:49:15	43	1	2				
B/264		06:51:48	43	0	2				
B/252		06:54:20	48	1	3				
B/240		06:56:46	47	1	3				
C/240		07:03:09	44	1	3				
C/252		07:06:11	43	1	3				
C/264		07:09:21	43	0	3				
C/276		07:12:32	43	1	2				
C/288		07:15:42	42	1	2				
C/300	2500	07:18:52	38	1	3		17.1	0.4	<0.1
C/312		07:22:02	36	1	2				
C/324		07:25:12	36	1	3				
C/336		07:28:23	37	0	2				
C/348		07:31:33	38	0	3				
C/360		07:34:36	40	1	3				

* See flight map for Arc; Radial from New York city centre.

Table F-1. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 21, 1986

Hydrocarbon	A/C Arc A 0555 - 0627 (EDT)	A/C Arc B 0632 - 0657 (EDT)	A/C Arc C 0703 - 0735 (EDT)
Ethane	7.7	4.4	3.9
Ethylene	0.1	0.2	1.0
Acetylene	0.2	0.4	0.8
Propane	2.9	2.5	2.3
Propene	-	-	0.3
i-Butane	0.7	0.5	0.6
n-Butane	1.6	1.1	1.6
i-Pentane	1.6	1.0	1.3
n-Pentane	0.8	0.5	0.7
Cyclopentane	-	-	-
Isoprene	-	-	-
2,3-Dimethylbutane	-	-	-
2-Methylpentane	0.5	0.2	0.2
3-Methylpentane	0.3	-	0.1
n-Hexane	0.3	0.1	0.2
Methylcyclopentane	-	-	-
Benzene	0.7	0.3	0.8
Cyclohexane	-	-	-
2-Methylhexane	-	-	-
3-Methylhexane	0.5	-	-
2,2,4-Trimethylpentane	0.4	-	-
Toluene	2.0	1.7	1.2
n-Octane	-	-	-
Ethylbenzene	0.3	-	0.7
p & *m*-Xylene	1.4	0.4	*
o-Xylene	1.4	0.4	1.4
Total Identified HC	23.4	13.7	17.1
TOTAL NMHC	27.7	14.6	20.9
% Paraffins	74	76	65
% Olefins	-	1	6
% Aromatics	25	20	24

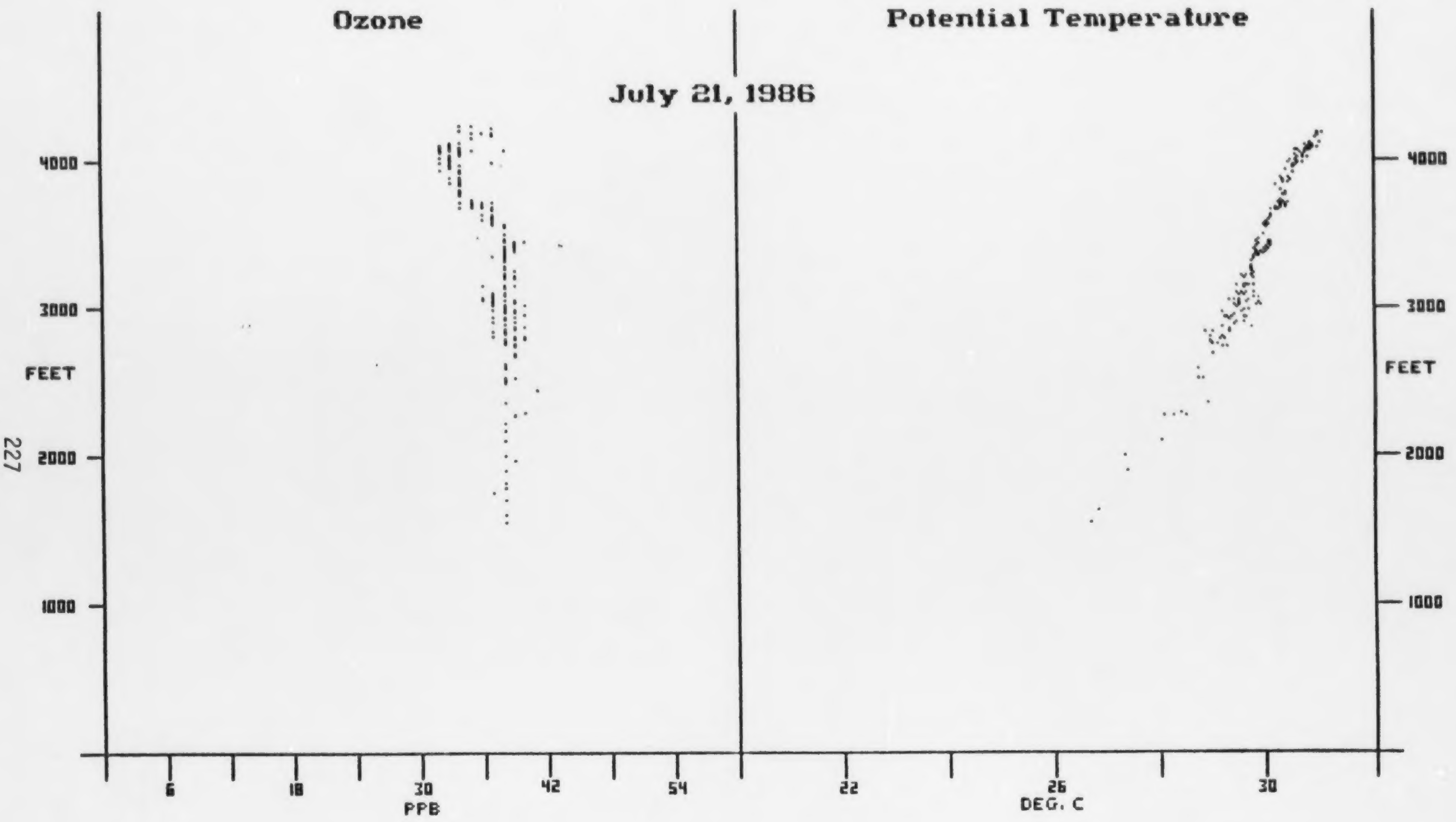
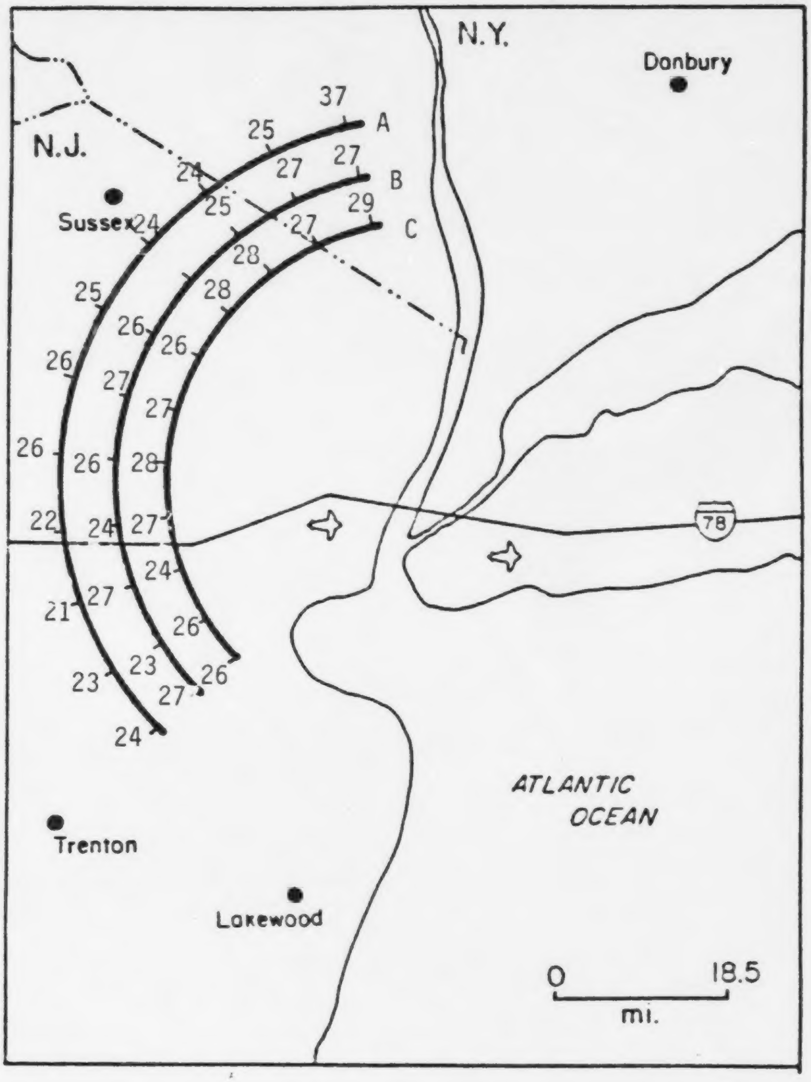


Figure F-2. Potential temperature and ozone changes with altitude on July 21, 1986.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ATLANTIC OCEAN
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Figure F-3. July 22, 1986 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude (AGL)

A: 0514 - 0543 at 2500'

B: 0547 - 0615 at 3500'

C: 0622 - 0651 at 3500'

Wind: 290° at 7 knots

July 22, 1986

Morning Mixing Level: 1800 feet

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (EDT)	O3 (ppb)	NO (ppb)	NOx (ppb)	Temp (C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/240		05:13:38	24	1	5	22.6			
A/252		05:16:25	23	0	5	22.1			
A/264		05:19:21	21	1	5	22.1			
A/276		05:22:16	22	0	4	22.0			
A/288		05:25:11	26	1	2	21.8			
A/300	2500	05:28:07	26	0	2	21.5	9.9	3.6	0.4
A/312		05:31:02	25	0	2	21.1			
A/324		05:33:57	24	1	1	20.7			
A/336		05:36:52	24	0	2	20.1			
A/348		05:39:48	25	0	3	20.1			
A/360		05:42:36	37	1	3	19.4			
B/360		05:47:27	27	1	2	19.6			
B/348		05:50:05	27	1	1	19.2			
B/336		05:52:52	25	0	1	18.7			
B/324		05:55:38		0	1	19.1			
B/312		05:58:24	26	1	2	19.1			
B/300	3500	06:01:11	27	0	2	19.3	15.8	2.4	0.3
B/288		06:03:57	26	0	3	19.3			
B/276		06:06:43	24	1	4	19.3			
B/264		06:09:29	27	0	4	19.0			
B/252		06:12:16	23	0	5	18.6			
B/240		06:14:55	27	1	5	18.5			
C/240		06:21:58	26	1	6	18.8			
C/252		06:24:46	26	1	6	19.1			
C/264		06:27:42	24	1	6	18.3			
C/276		06:30:38	27	0	3	18.5			
C/288		06:33:34	28	1	3	18.2			
C/300	3500	06:36:30	27			18.4	21.1	3.2	0.1
C/312		06:39:25	26	1	3	18.1			
C/324		06:42:21	28	0	2	18.2			
C/336		06:45:17	28	1	2	18.0			
C/348		06:48:13	27	1	2	17.9			
C/360		06:51:02	29	0	2	18.4			

* See flight map for Arcs; Radial from New York city centre.

Table F-2. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 22, 1986

Hydrocarbon	A/C Arc A 0514 - 0543 (EDT)	A/C Arc B 0547 - 0615 (EDT)	A/C Arc C 0622 - 0651 (EDT)
Ethane	2.2	2.2	3.7
Ethylene	0.1	0.2	-
Acetylene	0.2	0.4	0.6
Propane	0.8	1.1	1.8
Propene	-	-	-
i-Butane	0.2	0.6	0.7
n-Butane	0.8	1.3	2.0
i-Pentane	1.0	1.7	2.0
n-Pentane	0.3	0.7	0.9
Cyclopentane	-	-	-
Isoprene	-	-	-
2,3-Dimethylbutane	-	-	-
2-Methylpentane	-	0.2	0.3
3-Methylpentane	-	0.1	0.2
n-Hexane	-	0.1	0.1
Methylcyclopentane	-	-	-
Benzene	0.6	0.6	0.9
Cyclohexane	-	-	-
2-Methylhexane	-	-	-
3-Methylhexane	-	-	0.8
2,2,4-Trimethylpentane	-	-	-
Toluene	1.2	1.7	2.2
n-Octane	-	-	-
Ethylbenzene	0.3	0.7	0.5
p & *m*-Xylene	1.5	2.9	2.2
o-Xylene	0.7	1.3	2.2
Total Identified HC	9.9	15.8	21.1
TOTAL NMHC	17.1	16.4	23.0
% Paraffins	54	50	59
% Olefins	-	1	-
% Aromatics	43	46	38

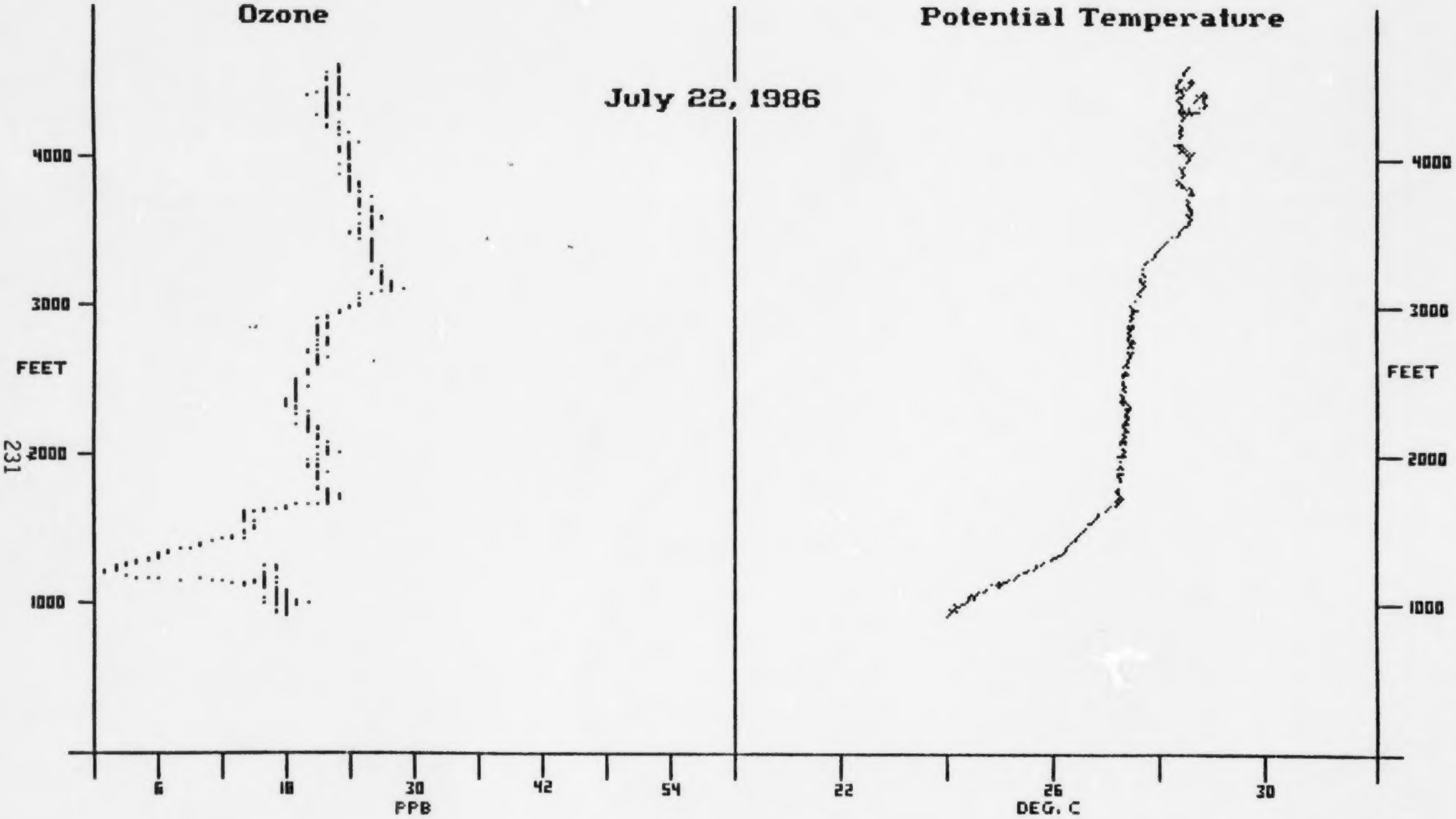
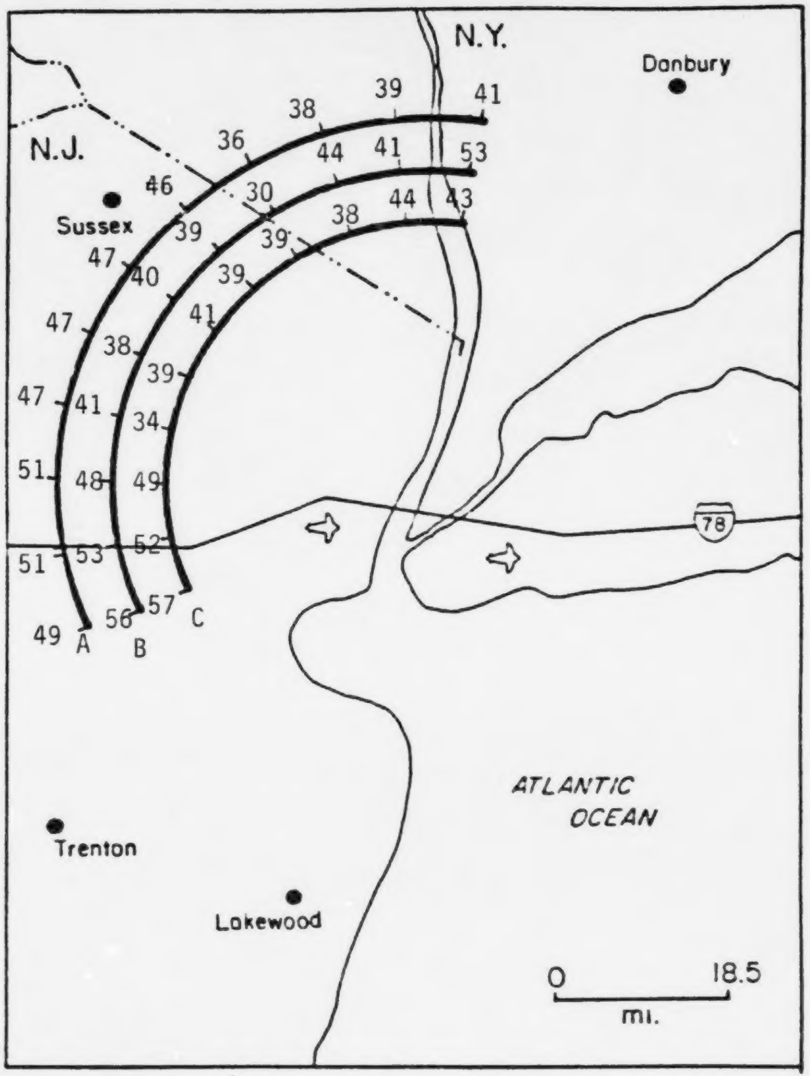


Figure F-4. Potential temperature and ozone changes with altitude on July 22, 1986.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ATLANTIC
OCEAN
Trenton
Lakewood
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Figure F-5. July 23, 1986 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude (AGL)

A: 0549 - 0619 at ~2500' (variable)

B: 0639 - 0706 at 3500'

C: 0712 - 0740 at 3500'

Wind: 310° at 5 knots

July 23, 1986

Morning Mixing Level: 2000 feet

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (EDT)	O3 (ppb)	NO (ppb)	NOx (ppb)	Temp (C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/260		05:48:40	49	2	3	21.9			
A/272		05:51:33	51	2	3	22.6			
A/284		05:54:34	51	2	3	23.0			
A/296		05:57:35	47	1	2	22.4			
A/308		06:00:36	47	2	2	21.6			
A/320	VARIABLE	06:03:37	47	2	3	21.7	20.8	2.3	0.7
A/332		06:06:38	46	1	3	21.4			
A/344		06:09:39	36	2	2	22.6			
A/356		06:12:40	38	1	1	22.5			
A/008		06:15:41	39	2	1	22.7			
A/020		06:18:35	41	2	3	21.7			
B/020		06:39:09	53	2	3	19.8			
B/008		06:41:45	41	2	2	20.2			
B/356		06:44:29	44	1	3	20.3			
B/344		06:47:13	30	2	5	20.1			
B/332		06:49:57	39	1	3	20.5			
B/320	3500	06:52:41	40	1	2	20.5	15.2	2.7	1.1
B/308		06:55:24	38	2	2	20.9			
B/296		06:58:08	41	1	3	20.7			
B/284		07:00:52	48	2	3	20.0			
B/272		07:03:36	53	2	3	20.0			
B/260		07:06:13	56	2	2	19.8			
C/260		07:12:01	57	2	3	19.6			
C/272		07:14:45	52	1	3	19.6			
C/284		07:17:36	49	2	2	19.4			
C/296		07:20:28	34			20.1			
C/308		07:23:20	39	2	4	20.0			
C/320	3500	07:26:12	41	2	3	20.1	48.5	2.9	1.1
C/332		07:29:03	39	2	3	19.7			
C/344		07:31:55	39	1	2	19.7			
C/356		07:34:47	38	2	2	19.6			
C/008		07:37:38	44	1	4	19.3			
C/020		07:40:23	43	2	2	19.0			

* See flight map for Arc; Radial from New York city centre.

Table F-3. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 23, 1986

Hydrocarbon	A/C Arc A 0549 - 0619 (EDT)	A/C Arc B 0639 - 0706 (EDT)	A/C Arc C 0712 - 0740 (EDT)
Ethane	3.5	3.5	3.7
Ethylene	0.3	0.4	3.3
Acetylene	0.5	0.4	1.0
Propane	2.3	1.6	2.0
Propene	-	0.2	-
i-Butane	1.0	0.7	1.0
n-Butane	2.5	1.1	4.9
i-Pentane	2.3	1.1	6.4
n-Pentane	1.1	0.6	1.1
Cyclopentane	-	-	-
Isoprene	-	0.1	1.3
2,3-Dimethylbutane	-	-	1.9
2-Methylpentane	0.5	0.1	0.9
3-Methylpentane	-	-	0.7
n-Hexane	0.3	0.1	0.3
Methylcyclopentane	-	-	-
Benzene	1.5	0.7	0.9
Cyclohexane	-	-	-
2-Methylhexane	0.1	-	1.8
3-Methylhexane	0.1	0.5	-
2,2,4-Trimethylpentane	0.1	-	8.6
Toluene	2.2	1.1	6.6
n-Octane	-	-	0.1
Ethylbenzene	0.3	0.2	0.4
p & *m*-Xylene	1.2	0.9	1.0
o-Xylene	1.0	1.9	0.6
Total Identified HC	20.8	15.2	48.5
TOTAL NMHC	30.3	22.2	56.6
% Paraffins	67	62	69
% Olefins	1	3	9
% Aromatics	30	32	20

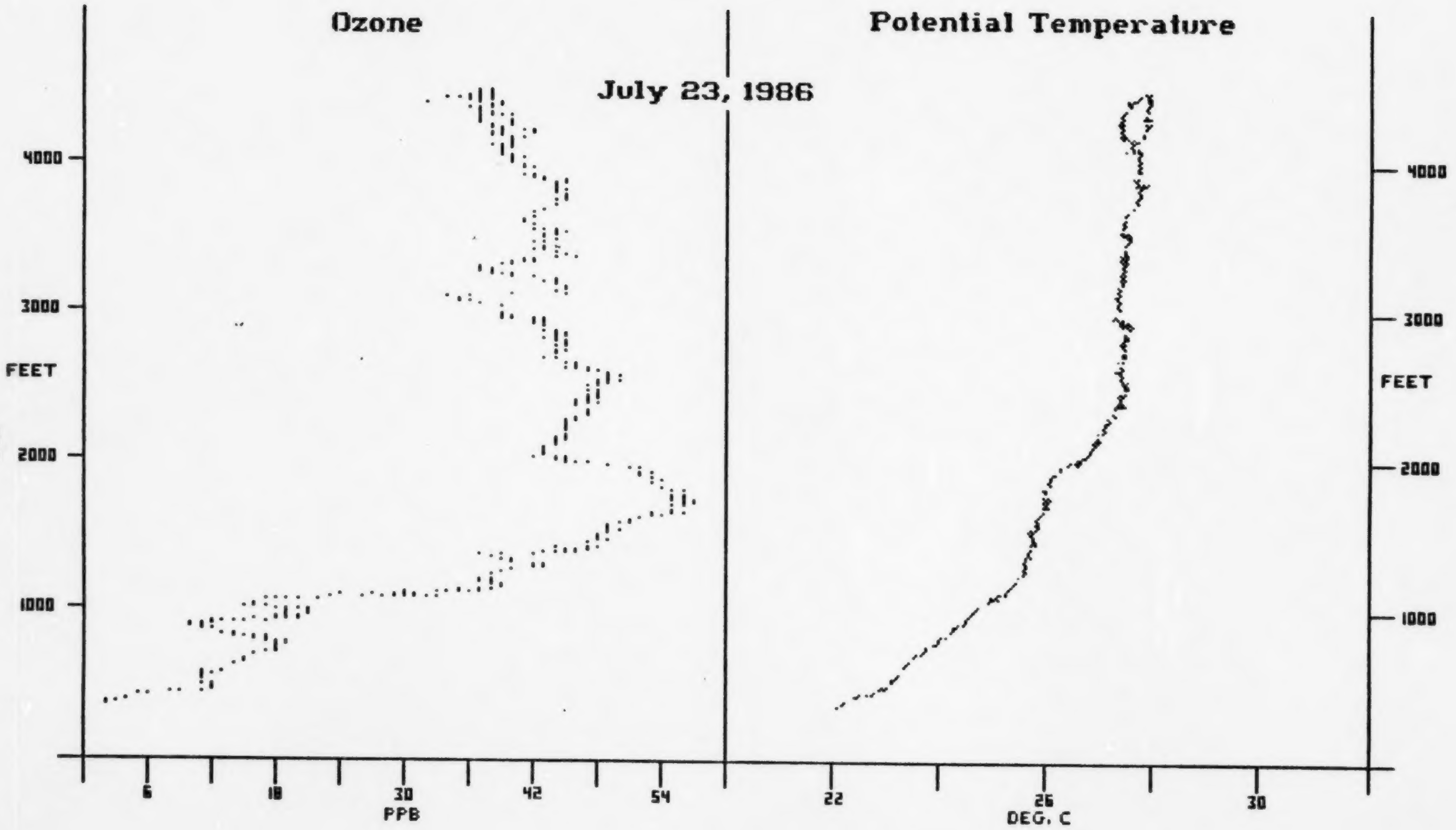
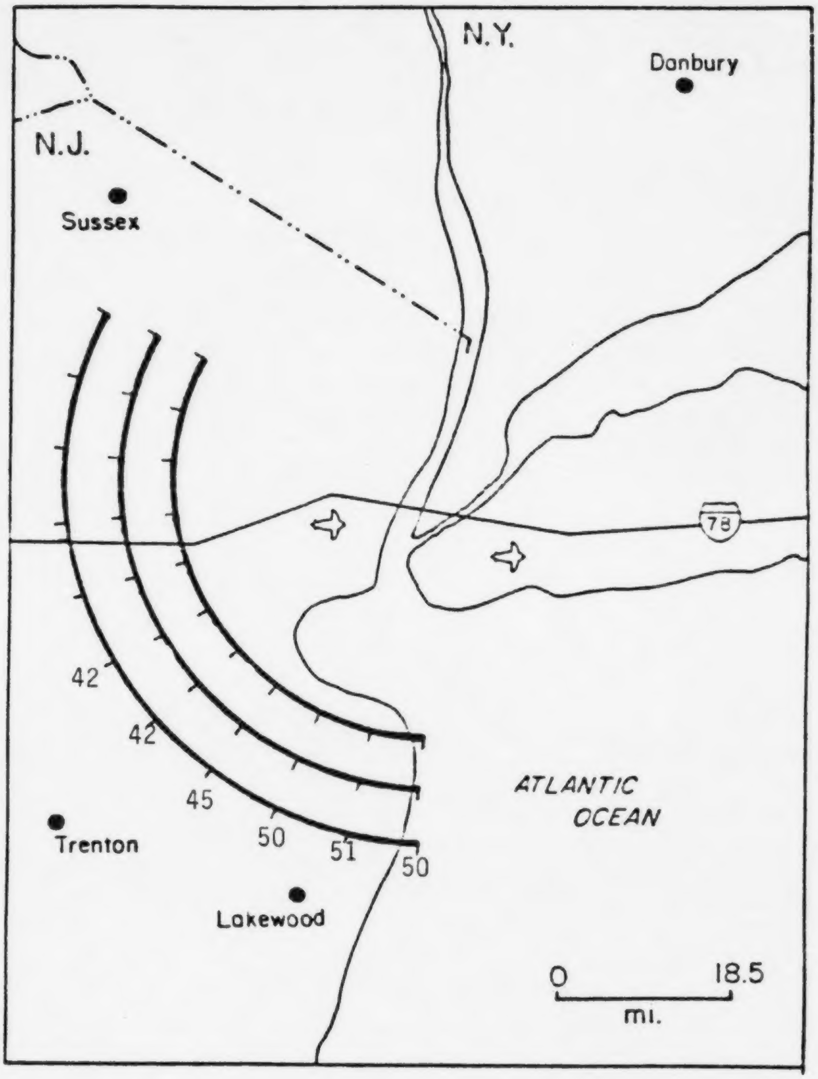


Figure F-6. Potential temperature and ozone changes with altitude on July 23, 1986.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Danbury
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Lakewood
0
18.5
mi.

Figure F-7. July 27, 1986 flight path with ozone concentrations (ppb) marked along the route.

Time: 0737 - 0754

Altitude: 3500'

Wind: 230^0 at 8 knots

Table F-4. Hydrocarbon Concentrations (ppbC) in Samples Collected on July 27, 1986

Hydrocarbon	A/C Arc C 0737 - 0754 (EDT)
Ethane	4.4
Ethylene	0.3
Acetylene	0.6
Propane	2.0
Propene	-
i-Butane	0.5
n-Butane	2.1
i-Pentane	1.7
n-Pentane	0.7
Cyclopentane	-
Isoprene	-
2,3-Dimethylbutane	-
2-Methylpentane	0.3
3-Methylpentane	-
n-Hexane	0.1
Methylcyclopentane	-
Benzene	1.1
Cyclohexane	-
2-Methylhexane	-
3-Methylhexane	0.2
2,2,4-Trimethylpentane	-
Toluene	1.5
n-Octane	-
Ethylbenzene	0.1
p & *m*-Xylene	0.5
o-Xylene	0.5
Total Identified HC	16.6
TOTAL NMHC	17.9
% Paraffins	72
% Olefins	2
% Aromatics	22

July 27, 1986

Morning Mixing Level: 900 feet

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (EDT)	O3 (ppb)	NO (ppb)	NOx (ppb)	Temp (C)	HC (ppbC)	Form (ppb)	Acet (ppb)
195		07:37:00	50	1	3	21.3			
207		07:40:16	51	1	3	21.5			
219		07:43:40	50	1	3	21.4			
231	3500	07:47:03	45	0	5	20.9	16.6	4.5	1.5
243		07:50:27	42			20.9			
255		07:53:44	42	1	3				

* See flight map for arcs; Radials from New York city centre.

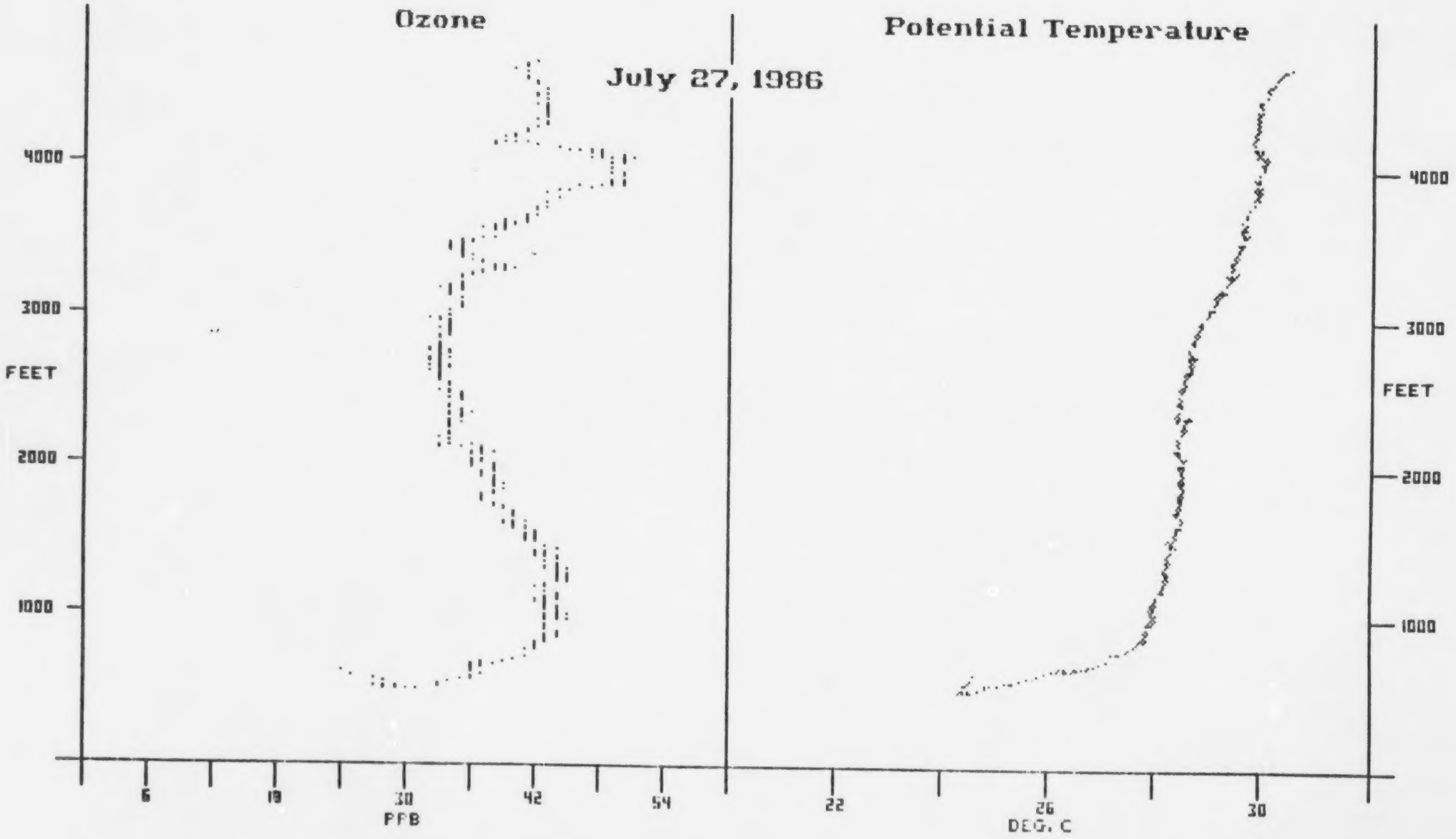

Figure F-8. Potential temperature and ozone changes with altitude on July 27, 1986.

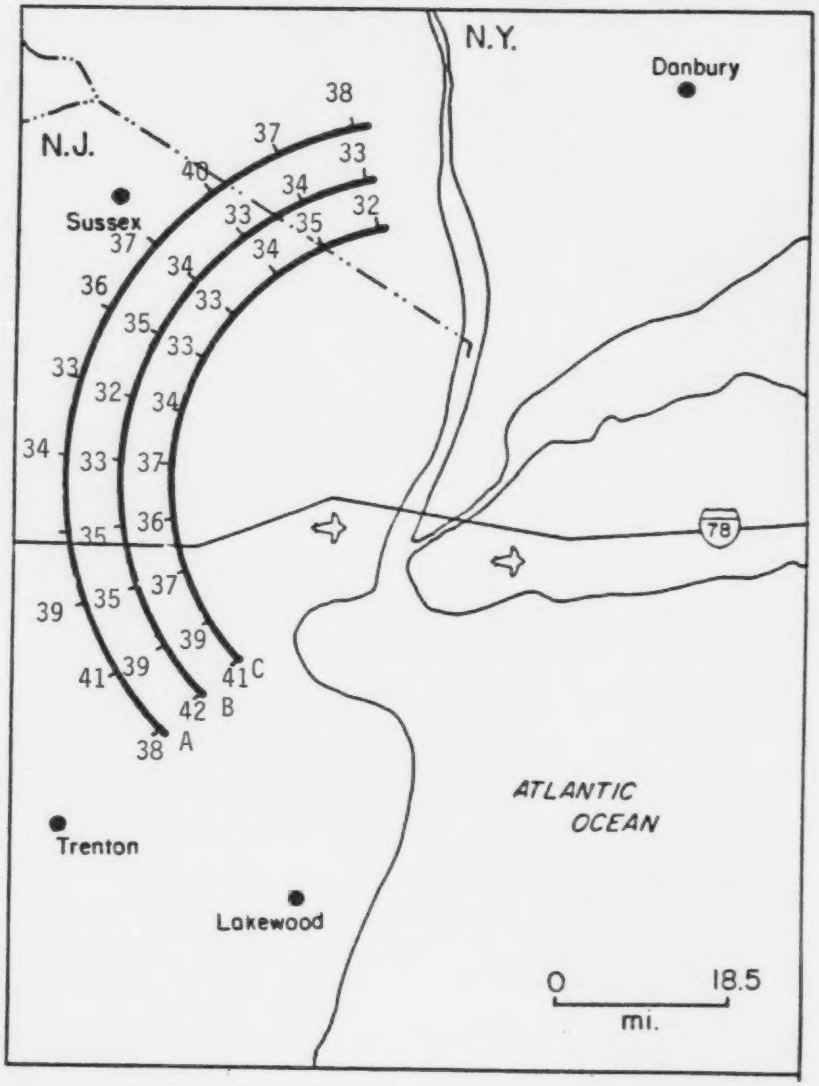
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Figure F-9. August 4, 1986 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude (AGL)

A: 0535 - 0605 at 2500'

B: 0611 - 0637 at 3500'

C: 0641 - 0711 at 2500'

Wind: 290° at 9 knots

August 4, 1986

Morning Mixing Level: <1000 feet

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (EDT)	O3 (ppb)	NO (ppb)	NOx (ppb)	Temp (C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/240	2500	05:35:14	38			22.2	10.0	1.5	0.9
A/252		05:38:09	41			22.1			
A/264		05:41:11	39			21.7			
A/276		05:44:14				21.3			
A/288		05:47:16	34			21.0			
A/300		05:50:19	33			20.5			
A/312		05:53:21	36			20.2			
A/324		05:56:24	37			20.0			
A/336		05:59:26	40			19.4			
A/348		06:02:29	37			20.0			
A/360		06:05:24	38			19.5			
B/360	3500	06:10:51	33			18.1	5.3	1.9	0.6
B/348		06:13:19	34			17.9			
B/336		06:15:54	33			11.6			
B/324		06:18:30	34			17.8			
B/312		06:21:06	35			17.9			
B/300		06:23:42	32			18.4			
B/288		06:26:17	33			18.9			
B/276		06:28:53	35			19.1			
B/264		06:31:29	35			12.2			
B/252		06:34:04	39			18.8			
B/240		06:36:33	42			18.3			
C/240	2500	06:40:59	41			20.6	9.6	1.3	0.6
C/252		06:43:55	39			20.1			
C/264		06:46:58	37			20.3			
C/276		06:50:02	36			19.8			
C/288		06:53:05	37			19.8			
C/300		06:56:09	34			19.6			
C/312		06:59:13	33			19.4			
C/324		07:02:16	33			19.1			
C/336		07:05:20	34			19.1			
C/348		07:08:23	35			19.2			
C/360		07:11:20	32			19.0			

* See flight maps for Arcs; Radials from New York city centre.

Table F-5. Hydrocarbon Concentrations (ppbC) in Samples Collected on August 4, 1986

Hydrocarbon	A/C Arc A 0535 - 0605 (EDT)	A/C Arc B 0611 - 0637 (EDT)	A/C Arc B 0611 - 0637 (EDT)	A/C Arc C 0641 - 0711 (EDT)
Ethane	3.2	7.7	3.0	3.3
Ethylene	-	0.5	-	-
Acetylene	0.2	0.3	0.2	0.3
Propane	1.5	2.4	0.5	1.7
Propene	-	-	-	-
i-Butane	0.5	0.5	0.2	0.5
n-Butane	1.2	1.1	0.4	1.3
i-Pentane	1.0		0.2	0.9
n-Pentane	0.4		0.1	0.7
Cyclopentane	-		-	-
Isoprene	-		-	-
2,3-Dimethylbutane	-		-	-
2-Methylpentane	-		-	-
3-Methylpentane	-		-	-
n-Hexane	-		-	-
Methylcyclopentane	-		-	-
Benzene	0.8		0.3	0.5
Cyclohexane	-		-	-
2-Methylhexane	-		-	-
3-Methylhexane	0.1		0.1	-
2,2,4-Trimethylpentane	-		-	-
Toluene	0.5		*	0.3
n-Octane	-		-	-
Ethylbenzene	-		-	-
p & *m*-Xylene	0.2		-	-
o-Xylene	0.4		0.3	0.1
Total Identified HC	10.0		5.3	9.6
TOTAL NMHC	13.2		10.7	10.8
% Paraffins	79		85	88
% Olefins	-		-	-
% Aromatics	19		11	9

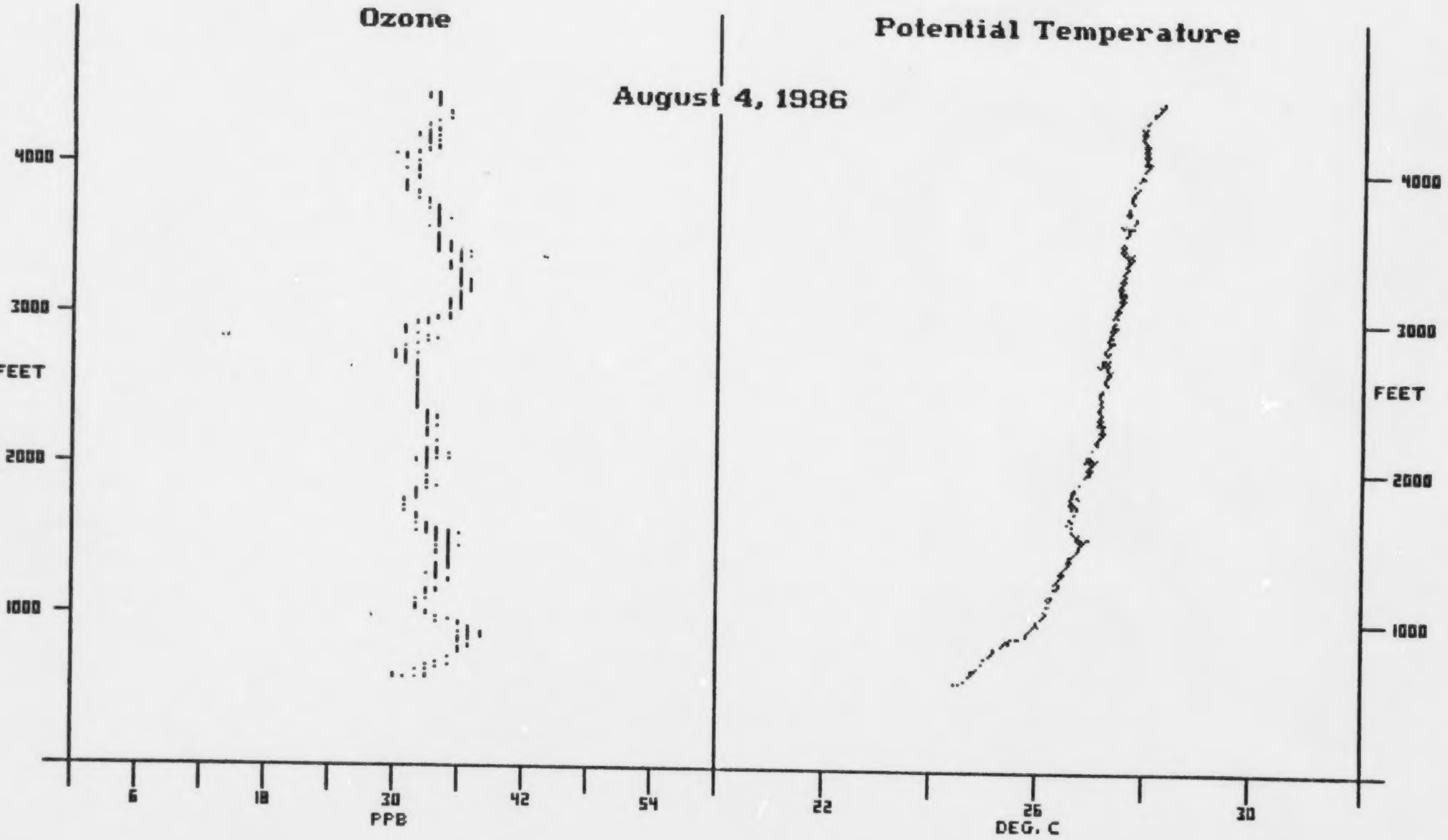
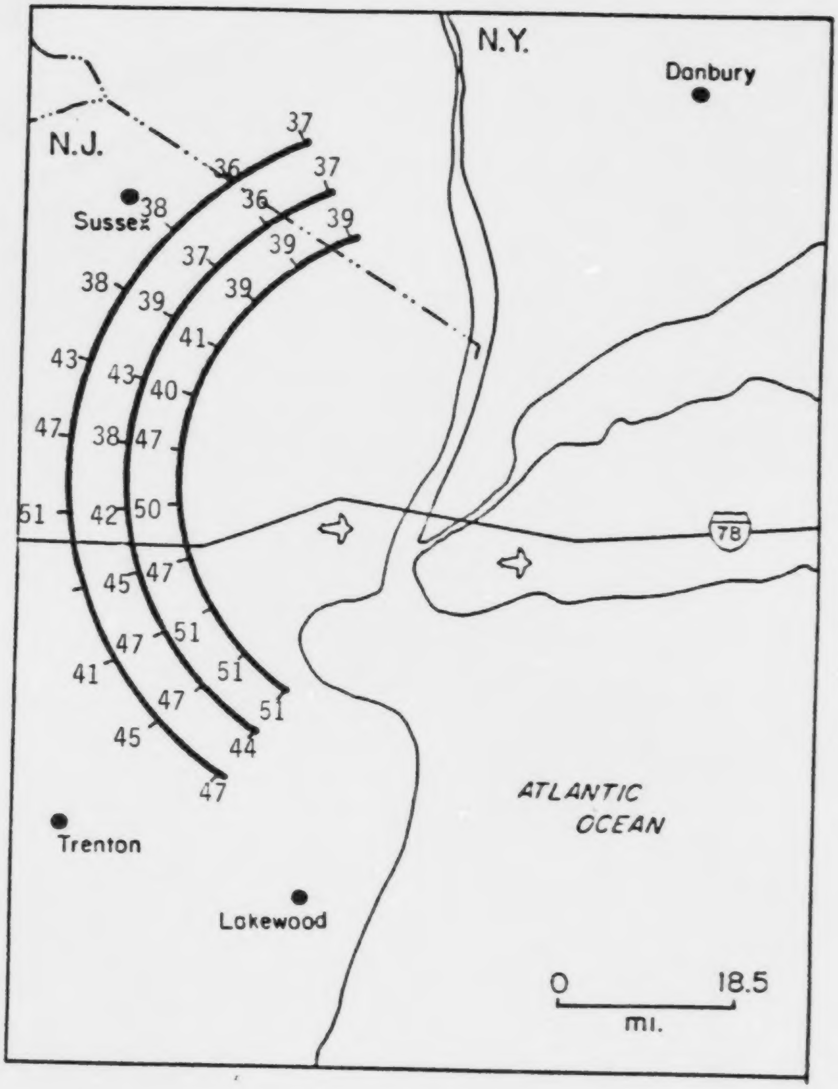


Figure F-10. Potential temperature and ozone changes with altitude on August 4, 1986.


N.Y.
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51

Figure F-11. August 5, 1986 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude (AGL)

A: 0533 - 0602 at 2500'

B: 0608 - 0636 at 3500'

C: 0640 - 0708 at 2500'

Wind: 280° at 3 knots

August 5, 1986

Morning Mixing Level: 900 feet

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (EDT)	O3 (ppb)	NO (ppb)	NOx (ppb)	Temp (C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/230		05:32:35	47			21.5			
A/242		05:35:23	45			21.5			
A/254		05:38:19	41			21.4			
A/266		05:41:15				21.6			
A/278		05:44:11	51			14.9			
A/290	2500	05:47:07	47			21.3	10.6	2.0	0.9
A/302		05:50:02	43			21.3			
A/314		05:52:58	38			21.0			
A/326		05:55:54	38			21.0			
A/338		05:58:50	36			20.8			
A/350		06:01:39	37			20.7			
B/350		06:07:45	37			18.6			
B/338		06:10:29	36			18.2			
B/326		06:13:20	37			18.1			
B/314		06:16:12	39			17.5			
B/302		06:19:03	43			18.3			
B/290	3500	06:21:55	38			18.5	14.3	1.9	0.8
B/278		06:24:46	42			18.3			
B/266		06:27:38	45			18.4			
B/254		06:30:29	47			18.3			
B/242		06:33:21	47			18.0			
B/230		06:36:05	44			18.0			
C/230		06:40:10	51			20.8			
C/242		06:42:50	51			20.5			
C/254		06:45:38	51			20.4			
C/266		06:48:26	47			20.4			
C/278		06:51:14	50			20.5			
C/290	2500	06:54:02	47			20.6	12.9	1.4	0.7
C/302		06:56:49	40			20.7			
C/314		06:59:37	41			20.6			
C/326		07:02:25	39			20.5			
C/338		07:05:13	39			20.1			
C/350		07:07:54	39			19.9			

*See flight map for Arcs; Radials from New York city centre.

Table F-6. Hydrocarbon Concentrations (ppbC) in Samples Collected on August 5, 1986

Hydrocarbon	A/C Arc A 0533 - 0602 (EDT)	A/C Arc B 0608 - 0636 (EDT)	A/C Arc C 0640 - 0708 (EDT)
Ethane	2.9	5.4	4.6
Ethylene	*	0.2	0.1
Acetylene	0.5	0.3	0.5
Propane	1.2	2.4	1.6
Propene	-	-	-
i-Butane	0.7	0.5	0.8
n-Butane	1.8	1.7	1.3
i-Pentane	1.1	1.1	0.9
n-Pentane	0.6	0.6	0.5
Cyclopentane	-	-	-
Isoprene	-	-	-
2,3-Dimethylbutane	-	-	-
2-Methylpentane	0.1	0.3	0.2
3-Methylpentane	-	0.1	-
n-Hexane	0.1	0.2	0.1
Methylcyclopentane	-	-	-
Benzene	0.7	0.8	0.5
Cyclohexane	-	-	-
2-Methylhexane	-	-	-
3-Methylhexane	-	-	-
2,2,4-Trimethylpentane	-	-	-
Toluene	0.9	0.7	0.6
n-Octane	-	-	-
Ethylbenzene	-	-	0.1
p & *m*-Xylene	-	-	0.3
o-Xylene	-	-	0.8
Total Identified HC	10.6	14.3	12.9
TOTAL NMHC	17.7	16.0	13.4
% Paraffins	80	86	76
% Olefins	-	1	1
% Aromatics	15	11	19

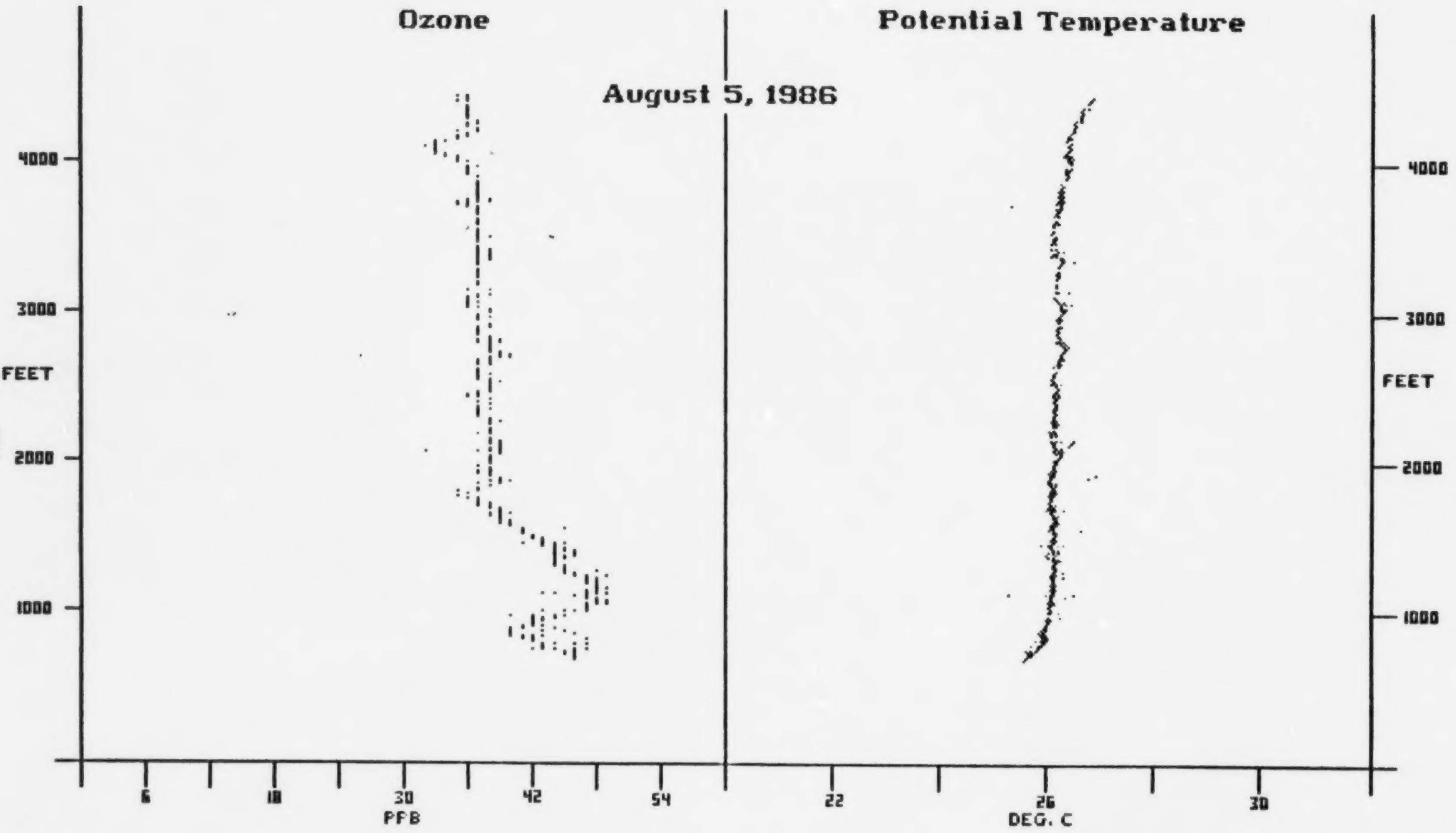
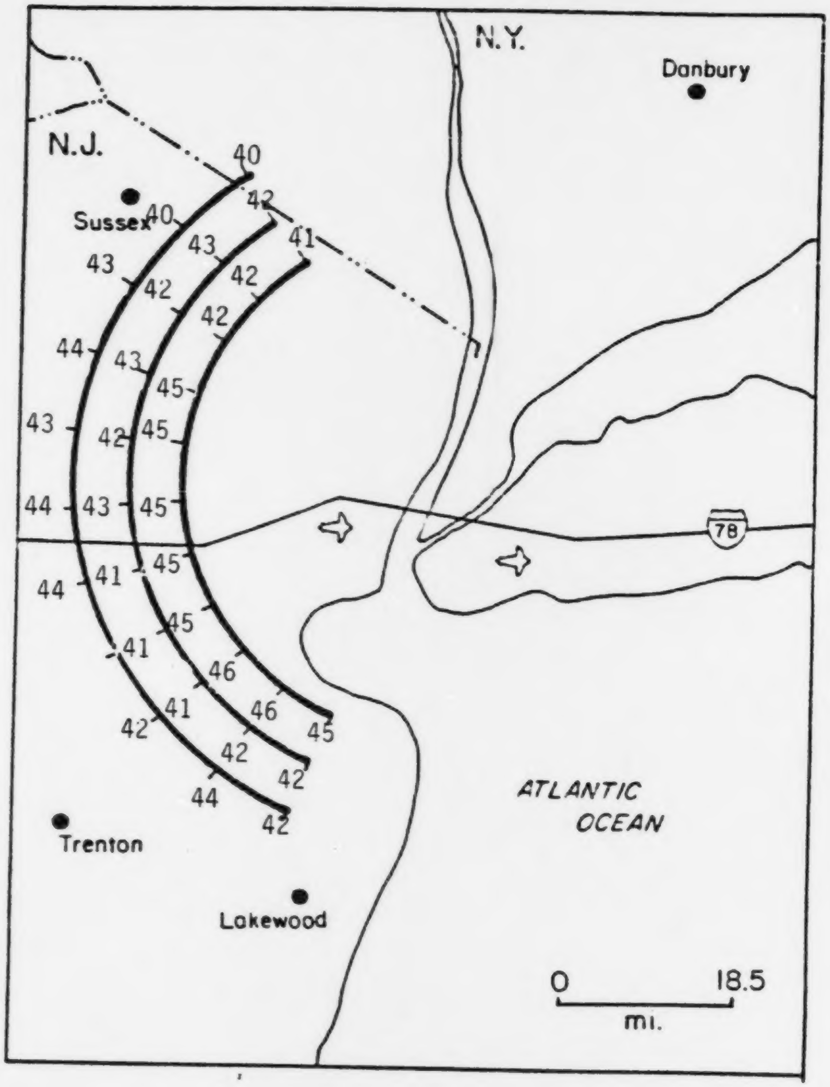


Figure F-12. Potential temperature and ozone changes with altitude on August 5, 1986.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Trenton
Lakewood
78
ATLANTIC
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mi.

Figure F-13. August 9, 1986 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude (AGL)

A: 0540 - 0611 at 3000'

B: 0618 - 0645 at 4000'

C: 0650 - 0718 at 3000'

Wind: 270° at 16 knots

August 9, 1986

Morning Mixing Level: 1400 feet

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (EDT)	O3 (ppb)	NO (ppb)	NOx (ppb)	Temp (C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/220	3000	05:40:29	42	1	5	23.2	15.5	1.7	0.6
A/232		05:43:26	44	2	3	23.3			
A/244		05:46:31	42	1	3	22.8			
A/256		05:49:37		1	4	22.9			
A/268		05:52:42	44	1	3	22.2			
A/280		05:55:47	44	1	3	22.2			
A/292		05:58:52	43	2	2	14.4			
A/304		06:01:57	44	1	3	21.7			
A/316		06:05:03	43	2	2	21.3			
A/328		06:08:08	40	1	2	20.7			
A/340		06:11:06	40	2	4	20.9			
B/340	4000	06:17:51	42	2	2	19.9	9.5	1.2	0.9
B/328		06:20:30	43	2	1	20.1			
B/316		06:23:17	42	2	1	20.1			
B/304		06:26:05	43	1	1	19.9			
B/292		06:28:52	42	2	1	20.5			
B/280		06:31:39	43	1	2	10.4			
B/268		06:34:26	41	1	3	20.6			
B/256		06:37:13	41	0	2	20.9			
B/244		06:40:01	41	1	2	20.6			
B/232		06:42:48	42	1	1	20.3			
B/220		06:45:28	42	1	2	10.4			
C/220	3000	06:49:57	45	1	3	21.5	16.4	0.9	1.1
C/232		06:52:39	46	1	1	20.9			
C/244		06:55:29	46	2	2	19.2			
C/256		06:58:19	45	1	3	21.7			
C/268		07:01:09	45	1	2	21.7			
C/280		07:04:00	45	1	2	21.6			
C/292		07:06:50	45	1	4	21.2			
C/304		07:09:40	45	2	2	21.1			
C/316		07:12:30	42	2	3	20.1			
C/328		07:15:20	42	1	3	20.1			
C/340		07:18:03	41	2	3	20.6			

*See flight maps for Arcs; Radials from New York city centre.

Table F-7. Hydrocarbon Concentrations (ppbC) in Samples Collected on August 9, 1986

Hydrocarbon	A/C Arc A 0540 - 0611 (EDT)	A/C Arc B 0618 - 0645 (EDT)	A/C Arc C 0650 - 0718 (EDT)
Ethane	5.2	3.0	5.0
Ethylene	-	-	-
Acetylene	0.3	0.2	0.5
Propane	3.0	1.6	2.8
Propene	0.1	-	-
i-Butane	0.7	0.3	0.9
n-Butane	1.9	0.8	1.7
i-Pentane	1.0	0.9	1.1
n-Pentane	0.5	0.3	0.6
Cyclopentane	-	-	-
Isoprene	-	-	-
2,3-Dimethylbutane	-	-	-
2-Methylpentane	0.1	0.1	0.1
3-Methylpentane	-	-	-
n-Hexane	0.1	-	0.1
Methylcyclopentane	-	-	-
Benzene	0.6	0.6	0.7
Cyclohexane	-	-	-
2-Methylhexane	-	0.1	-
3-Methylhexane	0.3	0.7	0.2
2,2,4-Trimethylpentane	-	-	0.1
Toluene	0.6	0.5	0.8
n-Octane	-	-	-
Ethylbenzene	0.1	-	0.2
p & *m*-Xylene	0.2	0.1	0.9
o-Xylene	0.8	0.3	0.7
Total Identified HC	15.5	9.5	16.4
TOTAL NMHC	28.8	12.8	16.8
% Paraffins	82	82	77
% Olefins	1	-	-
% Aromatics	15	16	20

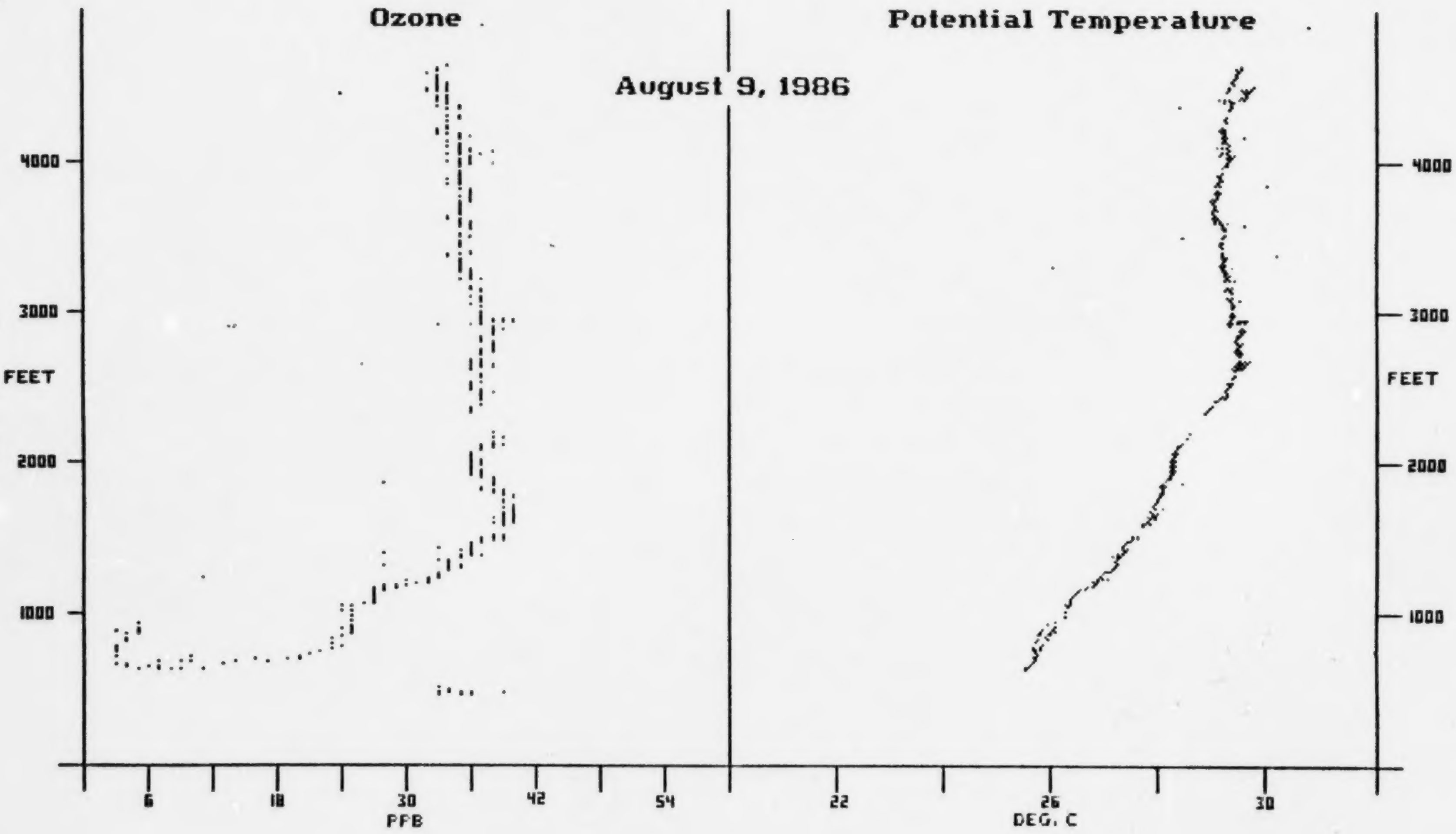
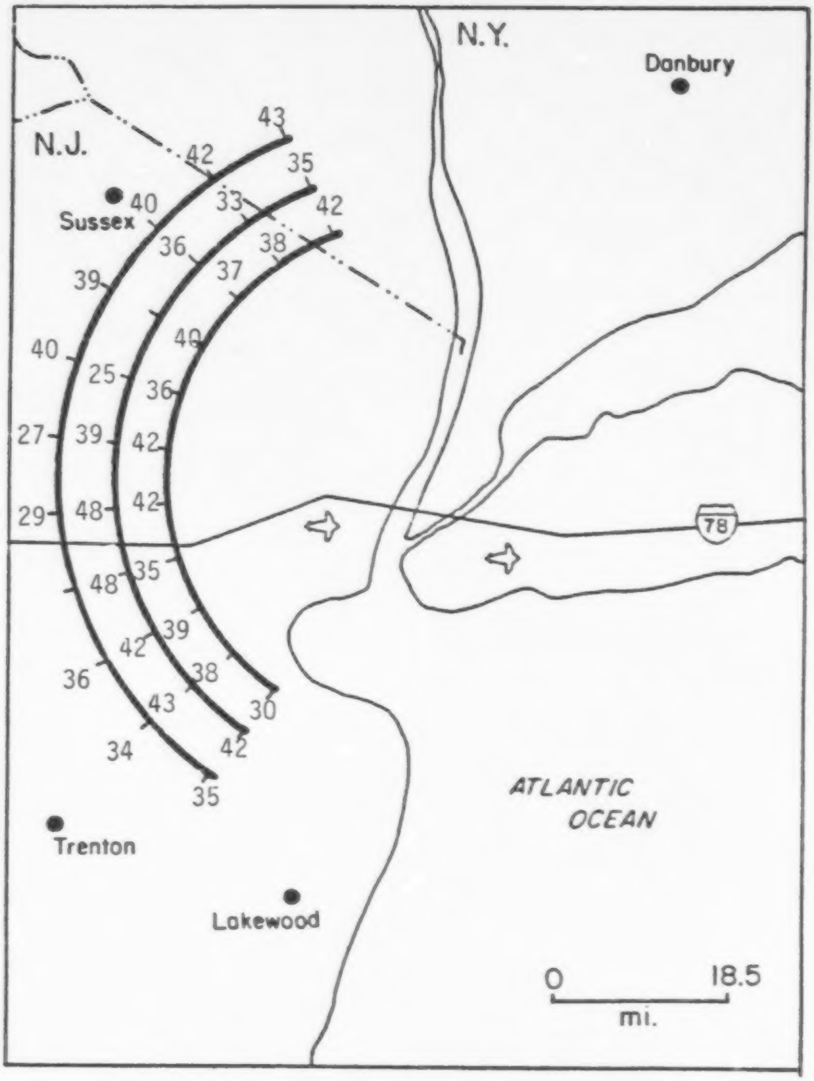


Figure F-14. Potential temperature and ozone changes with altitude on August 9, 1986.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Danbury
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Trenton
Lakewood
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Figure F-15. August 10, 1986 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude (AGL)

A: 0536 - 0605 at 2500'

B: 0612 - 0639 at 3500'

C: 0645 - 0715 at 2500'

Wind: 280° at 10 knots

August 10, 1986

Morning Mixing Level: <1000 feet

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (EDT)	O3 (ppb)	NO (ppb)	NOx (ppb)	Temp (C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/230	2500	05:35:51	35	2	2	22.6	9.8	3.1	0.4
A/242		05:38:41	34	2	3	22.7			
A/254		05:41:39	36	2	2	22.4			
A/266		05:44:36		2	3	22.5			
A/278		05:47:34	29	2	6	22.8			
A/290		05:50:32	37	1	3	22.2			
A/302		05:53:30	40	0	2	21.8			
A/314		05:56:28	39	1	3	21.1			
A/326		05:59:25	40	1	2	20.6			
A/338		06:02:23	42	2	2	20.3			
A/350		06:05:14	43	2	3	20.7			
B/350	3500	06:12:00	35	1	2	18.8	12.2	1.9	0.5
B/338		06:14:36	33	1	2	18.8			
B/326		06:17:20	36	2	1	18.8			
B/314		06:20:03		2	2	19.0			
B/302		06:22:47	25	2	6	19.1			
B/290		06:25:31	39	1	5	19.3			
B/278		06:28:15	48	1	3	19.5			
B/266		06:30:59	48	1	3	19.8			
B/254		06:33:42	42	1	3	20.0			
B/242		06:36:26	43	2	3	19.8			
B/230		06:39:03	42	2	3	19.6			
C/230	2500	06:45:00	30	2	7	21.4	11.8	1.6	0.3
C/242		06:47:52	38	2	4	21.5			
C/254		06:50:52	39	1	3	21.4			
C/266		06:53:52	35	2	5	21.2			
C/278		06:56:52	42	1	4	21.2			
C/290		06:59:53	42	1	4	20.9			
C/302		07:02:53	36	1	2	20.7			
C/314		07:05:53	40	1	3	20.5			
C/326		07:08:53	37	1	2	20.4			
C/338		07:11:53	38	2	3	19.7			
C/350		07:14:46	42	1	2				

* See flight map for Arcs; Radials from New York city centre.

Table F-8. Hydrocarbon Concentrations (ppbC) in Samples Collected on August 10, 1986

Hydrocarbon	A/C Arc A 0536 - 0605 (EDT)	A/C Arc B 0612 - 0639 (EDT)	A/C Arc C 0645 - 0715 (EDT)
Ethane	3.5	3.4	4.2
Ethylene	-	-	-
Acetylene	0.1	0.4	0.3
Propane	1.9	1.8	2.0
Propene	-	-	-
i-Butane	0.3	0.9	0.5
n-Butane	1.2	1.6	1.2
i-Pentane	0.8	1.2	0.9
n-Pentane	0.6	0.5	0.5
Cyclopentane	-	-	-
Isoprene	-	-	-
2,3-Dimethylbutane	-	-	-
2-Methylpentane	0.2	0.3	0.2
3-Methylpentane	-	0.1	0.1
n-Hexane	0.2	0.2	0.1
Methylcyclopentane	-	-	-
Benzene	0.5	0.5	0.4
Cyclohexane	-	-	-
2-Methylhexane	-	-	-
3-Methylhexane	-	0.1	-
2,2,4-Trimethylpentane	-	-	-
Toluene	0.3	0.7	0.7
n-Octane	-	-	-
Ethylbenzene	-	-	0.1
p & *m*-Xylene	-	-	0.2
o-Xylene	0.2	0.5	0.4
Total Identified HC	9.8	12.2	11.8
TOTAL NMHC	12.8	14.0	17.0
% Paraffins	89	83	82
% Olefins	-	-	-
% Aromatics	10	14	15

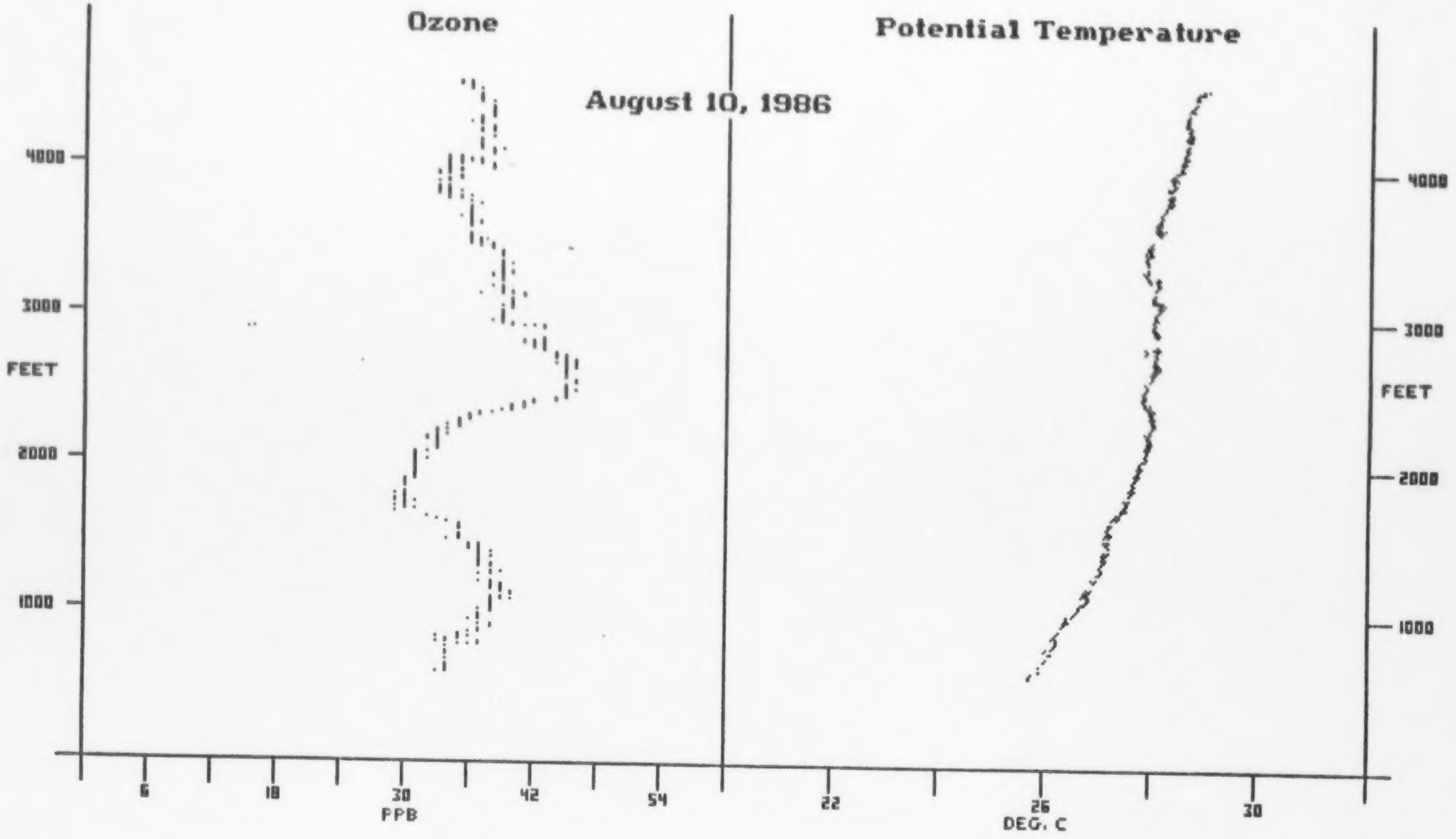

Figure F-16. Potential temperature and ozone changes with altitude on August 10, 1986.

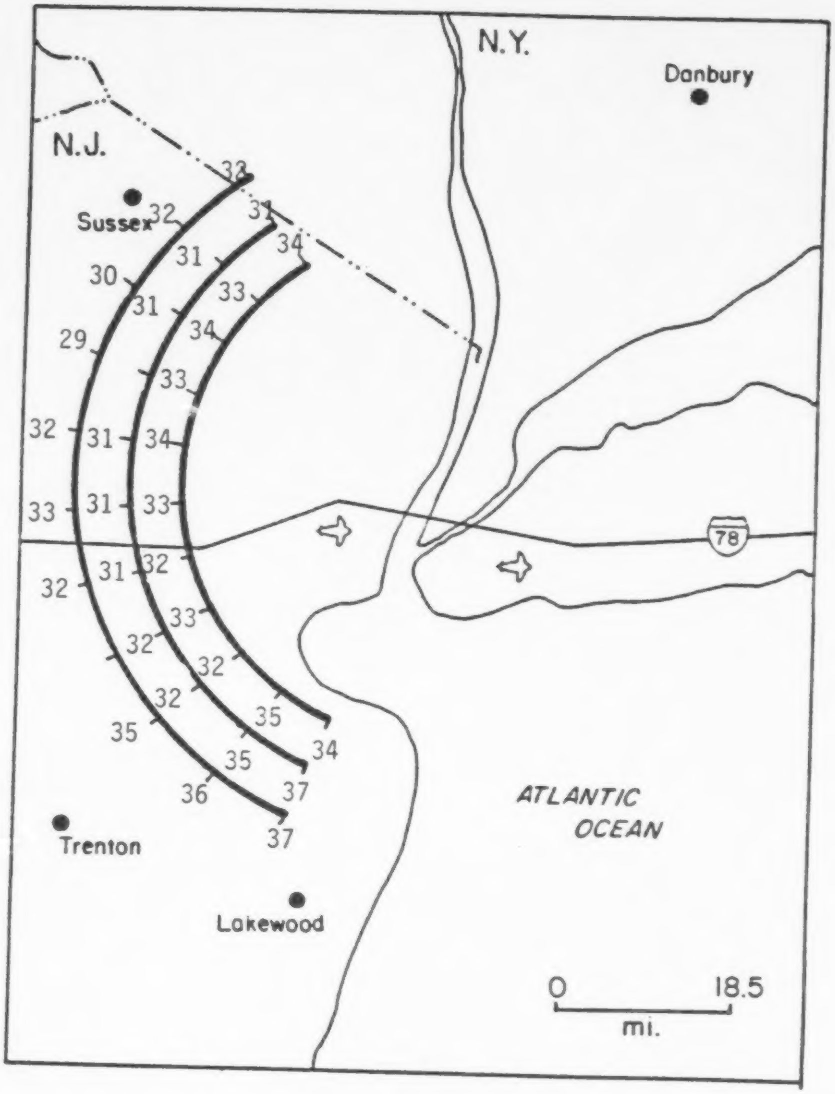
N.Y.
Danbury
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Figure F-17. August 11, 1986 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude (AGL)

A: 0549 - 0619 at 3000'

B: 0626 - 0653 at 4000'

C: 0657 - 0723 at 3000'

Wind: 270° at 22 knots

August 11, 1986.

Morning Mixing Level: 1800 feet

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (EDT)	O3 (ppb)	NO (ppb)	NOx (ppb)	Temp (C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/220		05:49:18	37	2	4				
A/232		05:52:13	36	3	4				
A/244		05:55:15	35	1	3				
A/256		05:58:18		3	3				
A/268		06:01:21	32	3	4				
A/280	3000	06:04:24	33	1	3		20.7	1.6	0.7
A/292		06:07:26	32	2	4				
A/304		06:10:29	29	1	4				
A/316		06:13:32	30	3	3				
A/328		06:16:34	32	3	4				
A/340		06:19:30	32	2	4				
B/340		06:26:04	31	1	3				
B/328		06:28:40	31	1	4				
B/316		06:31:23	31	0	3				
B/304		06:34:07		3	4				
B/292		06:36:51	31	2	3				
B/280	4000	06:39:35	31	2	3		22.0	0.9	0.1
B/268		06:42:18	31	1	3				
B/256		06:45:02	32	1	3				
B/244		06:47:46	32	1	3				
B/232		06:50:29	35	2	2				
B/220		06:53:06	37	2	2				
C/220		06:57:29	34	2	3				
C/232		07:00:00	35	2	1				
C/244		07:02:38	32	1	4				
C/256		07:05:17	33	2	3				
C/268		07:07:55	32	3	3				
C/280	3000	07:10:34	33				23.0	3.7	0.9
C/292		07:13:12	34	2	3				
C/304		07:15:51	33	2	2				
C/316		07:18:29	34	1	3				
C/328		07:21:08	33	1	2				
C/340		07:23:39	34	1	3				

* See flight map for Arc; Radila from New York city centre.

Table F-9. Hydrocarbon Concentrations (ppbC) in Samples Collected on August 11, 1986

Hydrocarbon	A/C Arc A 0549 - 0620 (EDT)	A/C Arc B 0626 - 0653 (EDT)	A/C Arc C 0657 - 0724 (EDT)
Ethane	7.1	7.9	8.6
Ethylene	0.4	-	0.2
Acetylene	0.4	0.3	0.5
Propane	4.8	4.6	4.8
Propene	0.1	-	0.1
i-Butane	1.1	1.2	1.1
n-Butane	2.2	2.4	2.8
i-Pentane	1.4	1.3	1.5
n-Pentane	0.7	0.9	0.9
Cyclopentane	-	-	-
Isoprene	-	-	-
2,3-Dimethylbutane	-	-	-
2-Methylpentane	0.4	0.4	0.5
3-Methylpentane	-	-	0.2
n-Hexane	0.4	0.3	0.3
Methylcyclopentane	0.1	0.1	0.1
Benzene	0.5	0.6	0.6
Cyclohexane	-	-	-
2-Methylhexane	-	-	-
3-Methylhexane	-	0.1	0.1
2,2,4-Trimethylpentane	-	-	-
Toluene	0.7	0.7	0.7
n-Octane	-	-	-
Ethylbenzene	-	0.1	-
p & *m*-Xylene	0.1	0.3	-
o-Xylene	0.3	0.8	-
Total Identified HC	20.7	22.0	23.0
TOTAL NMHC	21.0	25.1	26.0
% Paraffins	88	88	91
% Olefins	2	-	1
% Aromatics	8	11	6

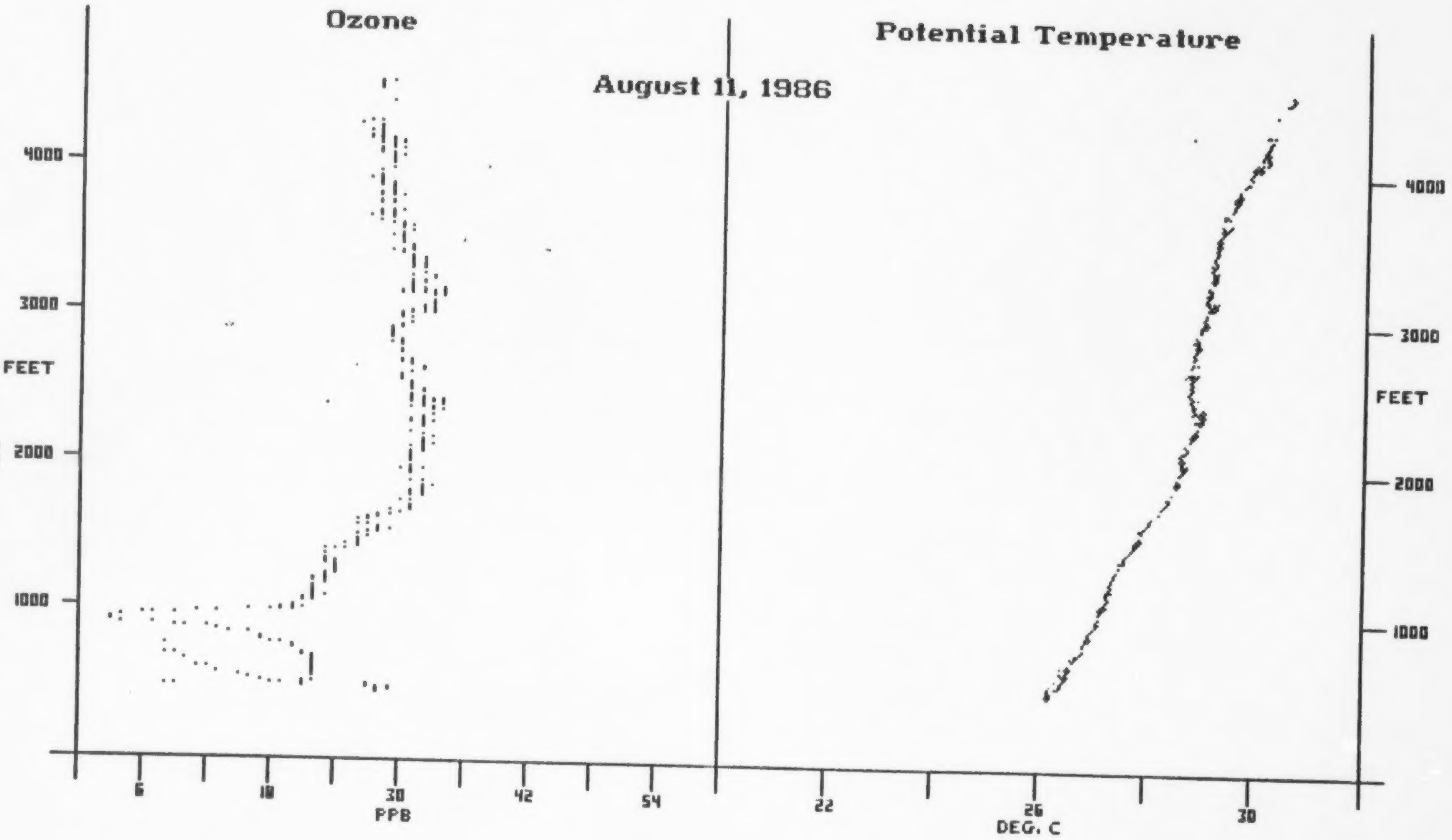

Figure F-18. Potential temperature and ozone changes with altitude on August 11, 1986.

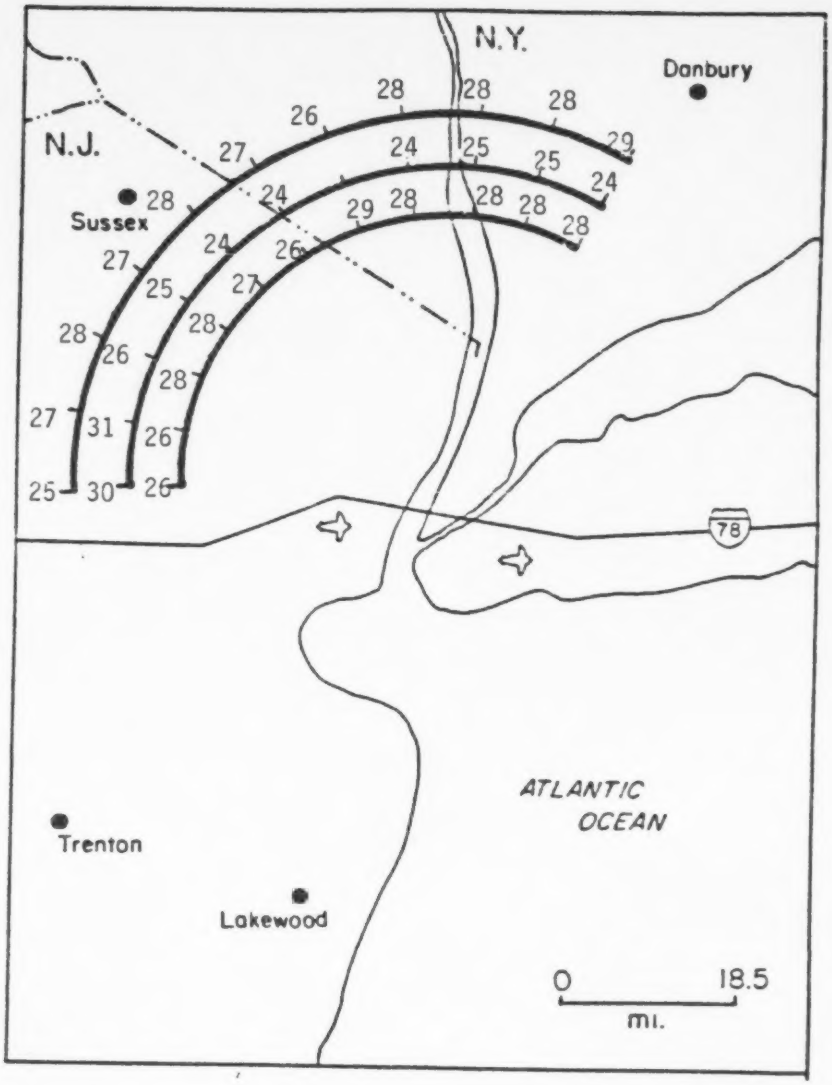
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Figure F-19. August 12, 1986 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude (AGL)

A: 0540 - 0611 at 3000'

B: 0618 - 0647 at 4000'

C: 0653 - 0720 at 3000'

Wind: 330° at 9 knots

August 12, 1986

Morning Mixing Level: Unknown

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (EDT)	O3 (ppb)	NO (ppb)	NOx (ppb)	Temp (C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/280	3000	05:39:50	25	1	3	17.8	10.6	1.2	0.7
A/292		05:42:51	27	1	3	16.7			
A/304		05:46:00	28	0	3	15.4			
A/316		05:49:09	27	1	3	15.0			
A/328		05:52:18	28	1	2	14.7			
A/340		05:55:27	27	1	3	14.8			
A/352		05:58:35	26	1	2	14.9			
A/004		06:01:44	28	1	3	15.2			
A/016		06:04:53	28	1	2	15.5			
A/028		06:08:02	28	1	2	15.4			
A/040		06:11:04	29	1	2	15.6			
B/040	4000	06:18:27	24	1	2	14.7	13.1	1.3	0.5
B/028		06:21:09	25	1	1	14.4			
B/016		06:23:59	25	1	2	14.3			
B/004		06:26:49	24	1	2	14.5			
B/352		06:29:39		1	2	14.2			
B/340		06:32:29	24	1	2	14.2			
B/328		06:35:19	24	2	1	14.1			
B/316		06:38:09	25	1	2	13.8			
B/304		06:40:59	26	1	2	14.3			
B/292		06:43:49	31	1	2	14.9			
B/280		06:46:32	30	1	2	15.4			
C/280	3000	06:52:34	26	1	2	16.3	25.8	1.2	0.7
C/292		06:55:10	26	1	1	16.2			
C/304		06:57:53	28	1	2	15.2			
C/316		07:00:37	28	1	2	14.9			
C/328		07:03:20	27	1	2	15.1			
C/340		07:06:04	26	2	2	14.9			
C/352		07:08:48	29	1	2	15.0			
C/004		07:11:31	28	1	1	15.4			
C/016		07:14:15	28	1	2	15.1			
C/028		07:16:58	28	1	1	14.9			
C/040		07:19:35	28	1	2	15.2			

* See flight map for Arc; Radial from New York city centre.

Table F-10. Hydrocarbon Concentrations (ppbC) in Samples Collected on August 12, 1986

Hydrocarbon	A/C Arc A 0540 - 0611 (EDT)	A/C Arc B 0618 - 0647 (EDT)	A/C Arc C 0653 - 0720 (EDT)
Ethane	2.6	7.4	6.2
Ethylene	-	-	13.1
Acetylene	0.5	0.3	0.4
Propane	0.7	1.9	0.8
Propene	-	-	-
i-Butane	0.3	0.5	0.4
n-Butane	0.8	1.0	0.7
i-Pentane	0.8	0.7	0.5
n-Pentane	0.5	0.3	0.4
Cyclopentane	-	-	-
Isoprene	-	-	-
2,3-Dimethylbutane	-	-	-
2-Methylpentane	0.3	0.1	0.2
3-Methylpentane	0.2	-	-
n-Hexane	0.2	0.1	0.3
Methylcyclopentane	-	-	-
Benzene	0.4	0.3	0.4
Cyclohexane	-	-	-
2-Methylhexane	-	-	-
3-Methylhexane	0.4	-	0.5
2,2,4-Trimethylpentane	-	-	-
Toluene	0.9	0.5	0.6
n-Octane	-	-	-
Ethylbenzene	0.2	-	-
p & *m*-Xylene	0.5	-	0.4
o-Xylene	1.3	-	0.9
Total Identified HC	10.6	13.1	25.8
TOTAL NMHC	14.4	14.7	27.1
% Paraffins	64	92	38
% Olefins	-	-	51
% Aromatics	31	6	9

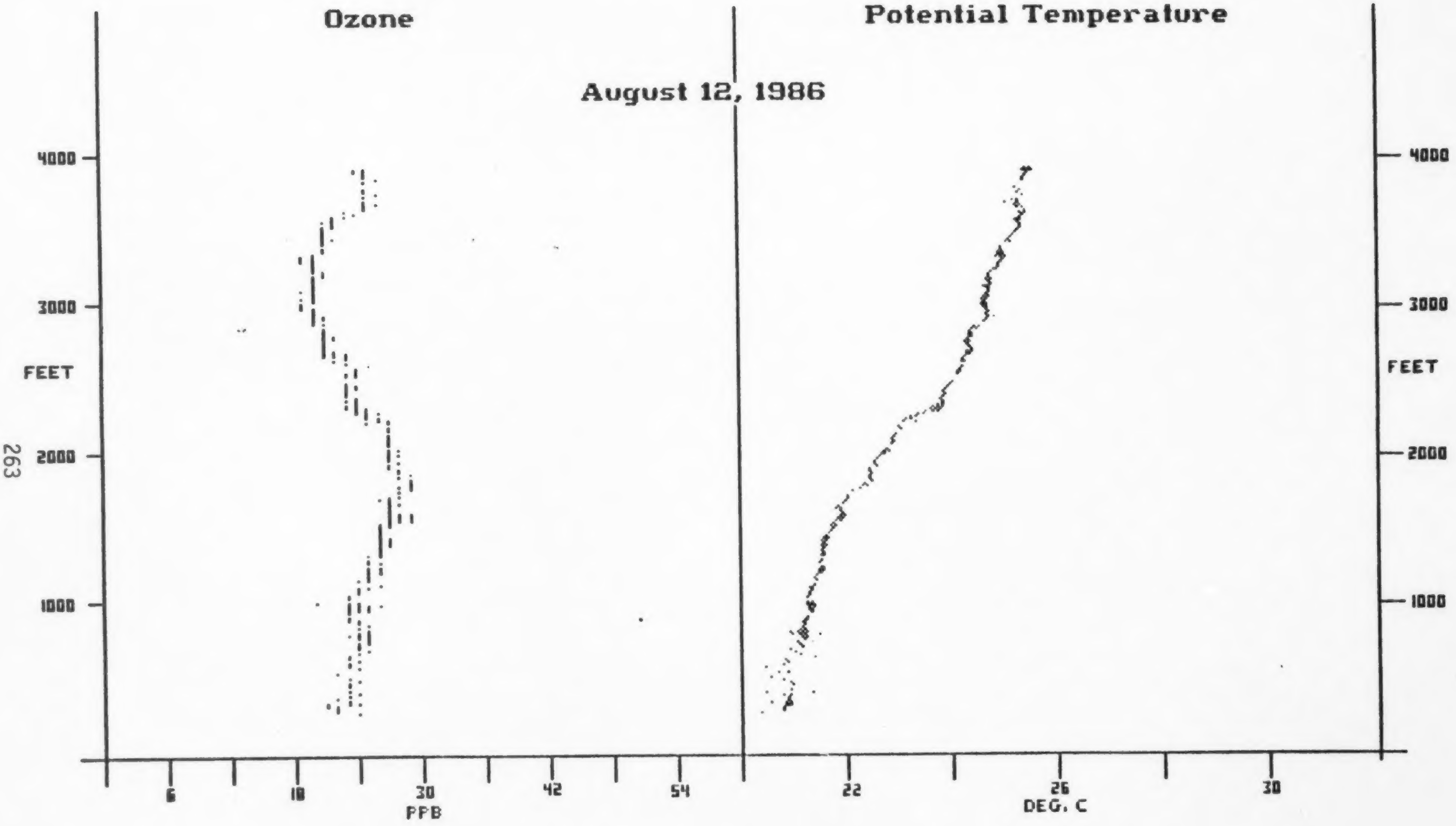
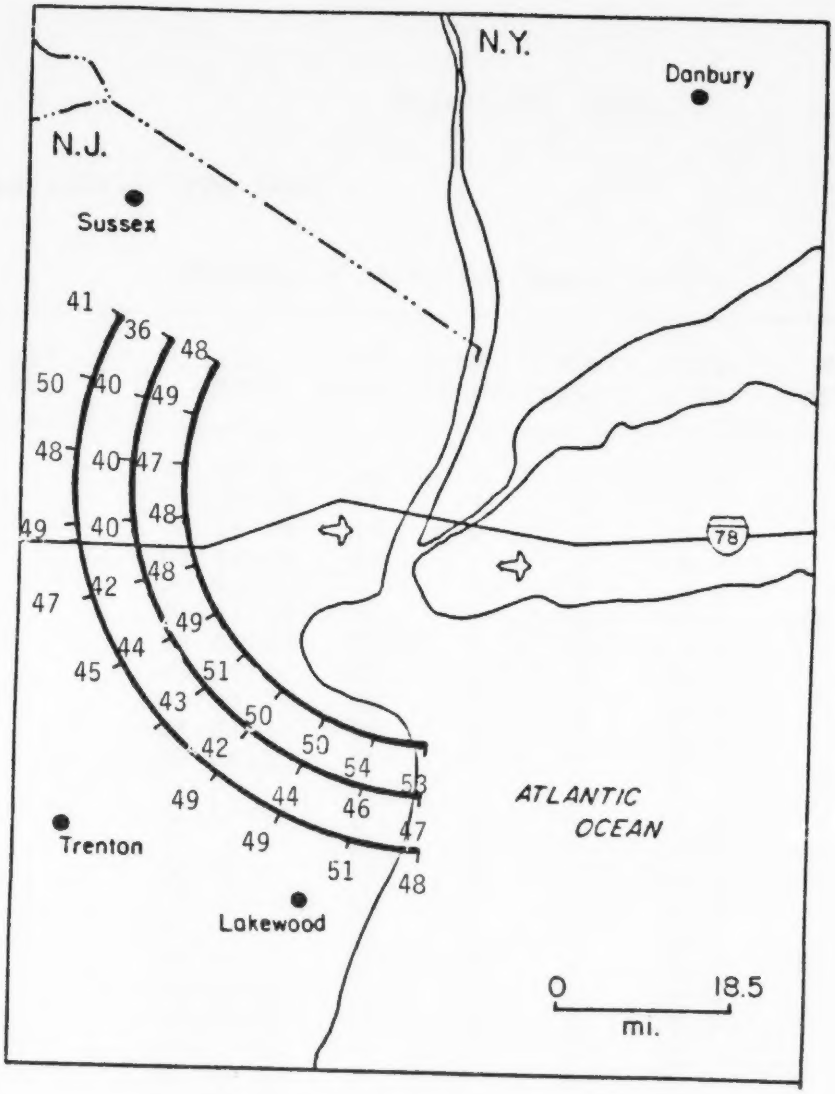


Figure F-20. Potential temperature and ozone changes with altitude on August 12, 1986.


N.Y.
Danbury
N.J.
Sussex
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78
ATLANTIC
OCEAN
Trenton
Lakewood
0
18.5
mi.

Figure F-21. August 14, 1986 flight path with ozone concentrations (ppb) marked along the route.

Time (EDT) and Altitude (AGL)

A: 0537 - 0606 at 2500'

B: 0611 - 0639 at 3500'

C: 0644 - 0712 at 2500'

Wind: light & variable

August 14, 1986

Morning Mixing Level: 1200 feet

Summary of Aircraft Measurements

Arc/Radial*	Alt (ft)	Time (EDT)	O3 (ppb)	NO (ppb)	NOx (ppb)	Temp (C)	HC (ppbC)	Form (ppb)	Acet (ppb)
A/195		05:37:23	48	1	2	18.6			
A/207		05:40:12	51	1	2	18.7			
A/219		05:43:08	49	0	2	18.9			
A/231		05:46:05	49	1	1	18.8			
A/243		05:49:01		1	2	18.8			
A/255	2500	05:51:58	45	1	2	18.8	19.3	2.0	1.0
A/267		05:54:54	47	1	3	19.0			
A/279		05:57:51	49	1	3	19.1			
A/291		06:00:47	48	0	3	19.2			
A/303		06:03:44	50	0	2	19.3			
A/315		06:06:33	41	1	2	19.3			
B/315		06:11:19	36	0	1	16.5			
B/303		06:14:01	40	0	1	16.4			
B/291		06:16:51	40	0	1	16.4			
B/279		06:19:41	40	1	1	16.4			
B/267		06:22:31	42	1	0	16.3			
B/255	3500	06:25:21	44	0	3	16.2	85.5	1.4	0.9
B/243		06:28:11	43	1	2	16.3			
B/231		06:31:01	42	0	2	16.3			
B/219		06:33:51	44	0	2	16.4			
B/207		06:36:41	46	1	2	16.3			
B/195		06:39:24	47	1	2	16.1			
C/195		06:43:38	53	0	1	18.0			
C/207		06:46:20	54	1	3	17.7			
C/219		06:49:10	50	1	3	17.4			
C/231		06:52:00	50	1	4	17.4			
C/243		06:54:50	51	1	3	17.8			
C/255	2500	06:57:41	49	1	3	18.0	22.4	2.4	0.7
C/267		07:00:31	48	2	2	18.2			
C/279		07:03:21	48	1	3				
C/291		07:06:11	47	1	2				
C/303		07:09:01	49	0	2				
C/315		07:11:44	48	1	3				

* See flight map for Arc; Radial from New York city centre.

Table F-11. Hydrocarbon Concentrations (ppbC) in Samples Collected on August 14, 1986

Hydrocarbon	A/C Arc A 0537 - 0607 (EDT)	A/C Arc B 0611 - 0639 (EDT)	A/C Arc C 0644 - 0712 (EDT)
Ethane	3.9	6.0	4.8
Ethylene	0.9	4.4	0.3
Acetylene	0.6	1.0	0.6
Propane	1.4	2.7	1.3
Propene	-	0.2	-
i-Butane	0.9	1.5	0.8
n-Butane	2.3	9.5	1.7
i-Pentane	2.3	12.5	2.1
n-Pentane	1.1	1.6	1.0
Cyclopentane	-	0.1	-
Isoprene	-	0.6	-
2,3-Dimethylbutane	-	4.2	-
2-Methylpentane	0.5	1.7	0.4
3-Methylpentane	0.4	0.9	0.5
n-Hexane	0.3	0.6	0.4
Methylcyclopentane	0.1	0.4	0.1
Benzene	0.9	1.3	0.8
Cyclohexane	-	-	-
2-Methylhexane	-	3.1	0.4
3-Methylhexane	0.3	0.5	1.3
2,2,4-Trimethylpentane	-	17.8	0.3
Toluene	1.8	12.2	1.9
n-Octane	-	0.4	0.5
Ethylbenzene	0.2	0.4	0.2
p & *m*-Xylene	0.5	1.0	0.6
o-Xylene	0.9	0.9	2.4
Total Identified HC	19.3	85.5	22.4
TOTAL NMHC	20.1	111	29.0
% Paraffins	70	74	70
% Olefins	5	6	1
% Aromatics	22	19	26

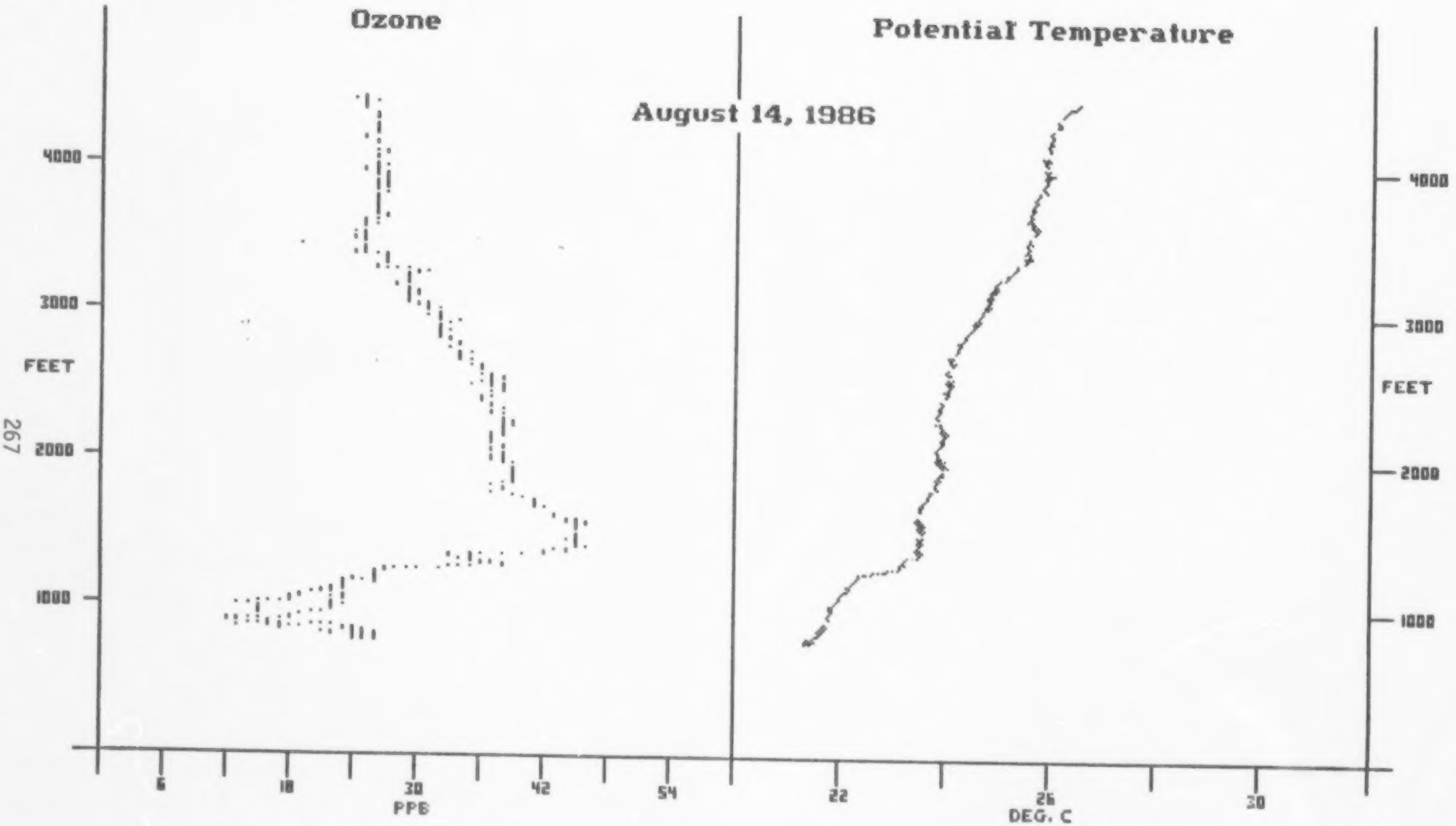

Figure F-22. Potential temperature and ozone changes with altitude on August 14, 1986.

APPENDIX G

Quality Assurance Document

EPA Grant No. CR812208

SECTION 1

PROJECT DESCRIPTION

The purpose of this field study was to collect NMOC data aloft that could be used for conducting modeling exercises with the EKMA procedure. Sampling was performed near Dallas-Ft. Worth, Tulsa, Atlanta, Birmingham, Philadelphia and New York City during the summers of 1985 and 1986. An instrumented aircraft was employed to measure NMOC, ozone and oxides of nitrogen in background air masses advected into each of these urban areas during the early morning hours. Special emphasis was placed on NMOC speciation and in particular the low molecular weight aldehydes. Measurements were concentrated in the layer above the morning surface inversion but below the normal afternoon mixing height. Instrumentation onboard the aircraft was used to define the depth of the morning surface inversion upwind of the urban area.

SECTION 2

AIRCRAFT STUDIES

AIRCRAFT DESCRIPTION

An instrumented Cessna 340 was used for airborne sampling. A low wing, twin engine airplane, the 340 is able to carry a pilot, an instrument operator and approximately 500 pounds of equipment. Air for analysis was brought into the aircraft through a 10.2 cm diameter sampling probe extending approximately 10-inches outboard of the right side of the fuselage. The probe was connected to a 4-inch diameter, stainless steel manifold inside the aircraft which extended down the right side of the cabin. Air from the sampling manifold entered the instruments through .635 cm Teflon tubing. The large size of the sampling probe and manifold provided ample air flow for all equipment.

A Topaz solid-state inverter was used to convert the 28 VDC aircraft generator output to 120 VAC for operating the air pollutant analyzers. The inverter provided about 1000 watts of usable power. The aircraft was equipped with Cessna navigational instruments and receivers. Certified accuracy of the altimeter was ±100 ft. The accuracy of the air speed indicator was ±1%. Aircraft Radio Corporation (Cessna) receivers were employed for obtaining very high frequency omni-directional range (VOR) and distance measuring equipment (DME) readings. VOR accuracy was certified to be within ±4° and DME accuracy was ±2%. The aircraft was equipped with a random navigation (R-Nav) system. Figure G-1 provides a schematic diagram of the airborne laboratory.

AIR QUALITY INSTRUMENTATION

Air quality instrumentation employed in the aircraft is listed in Table G-1. In addition, this table includes: 1) instrument range settings employed during the study, 2) instrument resolution, and 3) instrument response time (90% of full scale). Table G-2 summarizes precision and accuracy data for the ozone monitor and the oxides of nitrogen analyzer. The precision value is based on repetitive span checks conducted throughout the study period (see Table G-3). Accuracy is based on audits conducted during the summers of 1985 and 1986. (Table G-4).

TABLE G-1. AIRCRAFT AIR QUALITY INSTRUMENTATION.

Parameter	Instrument (S/N)	Analysis Technique	Ranges	Resolution	Response Time (sec)
Ozone	CSI 2000 (8038)	Chemilum	0-200(a)	~5(a)	~5
NO/NO_x	ML 8440 HP (1226)	Chemilum	0-200(a)	~5(a)	~5
Temperature	Metrodata M-8 (100)	Bead Thermister	-50 - +50(b)	0.5(b)	5
Relative Humidity	Metrodata M-8 (100)	Carbon Strip	30 - 95(c)	8(c)	5

a units = ppb b units = °C c units = %

TABLE G-2. PRECISION AND ACCURACY RESULTS

Parameter	Model	Precision (% SD)	Accuracy (%)	Noise (% fs)	Altitude Corrected
O_3	CSI 2000	1.9 (1985) (a) 7.9 (1986)	14.7 (b)	2	yes
NO/NO_x	ML 8440 HP	---	3.9/12.8 (b)	3	no

(a) Based on in-flight span checks
(b) Based on audits

TABLE G-3. OZONE SPAN DATA

Date	Response (millvolts)	Date	Response (millvolts)
7/7/85	26.0	8/13/85	25.0
7/8	26.0	8/15	25.0
7/9	26.0	8/16	25.0
7/10	26.0	8/19	26.0
7/11	26.0	8/20	25.0
7/13	26.0	8/21	26.0
7/14	26.0	8/22	25.5
7/16	25.5	8/23	26.0
7/19	26.0	8/26	25.5
7/20	25.5	8/27	25.0
7/21	26.5	8/28	25.0
7/22	26.0	8/29	26.5
7/23	26.0		
7/24	26.0		
Mean (1985) 25.7 mv; SD (1985) 0.5 mv; CV (1985) 1.9%			
7/8/86	20.5	7/27/86	24.0
7/10	22.4	7/30	23.0
7/11	20.2		
7/15	19.0	8/5	24.2
7/16	18.5	8/6	24.0
7/21	23.0	8/9	24.0
7/22	24.0	8/10	24.0
7/23	24.0	8/11	24.0
7/24	23.7	8/12	23.0
7/25	24.0	8/14	23.0
Mean (1986) 22.8 mv; SD (1986) 1.8 mv; CV (1986) 7.9%			

TABLE G-4. OZONE AND OXIDES OF NITROGEN AUDIT DATA

Date	Ozone			Nitric Oxide			Nitrogen Dioxide		
	Input (ppb)	Meas'd (ppb)	Δ (%)	Input (ppb)	Meas'd (ppb)	Δ (%)	Input (ppb)	Meas'd (ppb)	Δ (%)
7/11/85[*]	41	37	-9.8	65	*	*	65	67	3.1
	174	143	-17.8	170	*	*	170	153	-10.0
	435	360	-17.2	420	*	*	420	382	-9.0
7/24/85[+]	59	53	-10.2	83	75	-9.4	78	60	-23.1
	180	165	-8.3	180	157	-12.8	183	139	-24.0
	401	370	-7.7	400	361	-9.8	395	300	-24.1
8/19/85[¶]	40	35	-12.5	39	43	11.0	40	44	9.5
	120	96	-20.0	80	86	7.4	81	80	-0.7
	160	126	-21.3	160	144	-10.0	162	139	-14.2
8/27/85[§]	56	47	-16.0	-	-	-	-	-	-
	177	146	-17.5	-	-	-	-	-	-
	404	331	-18.1	-	-	-	-	-	-

[*] Texas Air Control Board
[+] Tulsa County Health Department
[¶] Georgia Department of Natural Resources
[§] Jefferson County Department of Health

- Audit not conducted for the NO_x instrument
* Audit data results not valid

AIRCRAFT SAMPLING

Flight missions were flown during the early morning hours (5-9 am). The flights began with a climb to approximately 6000 ft. and a spiral descent to about 100 ft. above the surface. These vertical measurements were generally performed upwind of the urban area. The plane then made a series of three upwind arcs at distances of 35, 30 and 25 nautical miles from the city center. The inner and outer arcs were usually flown at 2000 ft. and the middle arc at 3000 ft. The altitudes for these flights were varied based upon information of surface mixing layer determined from the vertical spirals. Aircraft sampling speeds varied between 130-170 mph. At spiral points, the aircraft descent rate was 500 ft/min with standard 2° turns.

Ozone, oxides of nitrogen, temperature and relative humidity data were collected continuously along each flight arc. Hydrocarbon, aldehyde and PAN samples were integrated over the major portion of each arc.

CALIBRATION PROCEDURES

A summary of calibration procedures for each air quality monitor is outlined below. Table G-5 lists calibration data for the O_3 and NO/NO_x analyzers.

Ozone - A multi point calibration was performed on the airborne ozone analyzer prior to the start of the field study. A MEC 1000 ozone generator was utilized to provide known concentrations in the 0-200 ppb range. Ozone generator output was established by UV photometry.

Oxides of nitrogen - Prior to the field study, a comprehensive calibration check was performed on the ML 8440 HP in our home laboratory. Various nitric oxide concentrations in the 0 to 50 ppb range were generated using a Meloy Model CN 020 nitrogen oxides/ozone calibrator using a cylinder of a certified NO in N_2 mixture (cylinder CC444 from Airco). The results are shown in Table G-5.

TABLE G-5. OZONE AND OXIDES OF NITROGEN CALIBRATION RESULTS.

Parameter	Method	Date	Concentration (ppb) Input	Concentration (ppb) Measured
NO/NO_x	Gas phase dilution Meloy CN020	6/14/85	15	14/14
			18	18/18
			22	22/22
			27	28/28
			37	37/37
	Permeation Tube (gas phase-low loss)	7/12/86	16	16/16
			23	23/22
			34	35/35
			44	43/44
	"	8/5/86	16	17/17
			23	23/33
			34	33/34
	Transfer std. MEC 1000 O_3 Generator	6/11/85	14	14
			50	47
			89	78
			104	111
			177	181
			257	256
	"	7/30/85	0	0
			14	20
			50	51
			89	80
	Dasibi O_3	6/30/86	0	0
			10	9
			20	20
			40	40
			80	80
			100	100

Meteorological Parameters - Calibration curves supplied by the manufacturer were used to convert sensor output signals to appropriate temperature and relative humidity readings.

DATA PROCESSING

During 1985, data collected in the aircraft were recorded on disks using an Hewlett Packard 3497 data acquisition system interfaced with an HP-85 microcomputer. An IBM Portable PC with a metra-Byte Model Dash-8 analog to digital converter board was used to record data during the 1986 flights. Instrument and sensor responses were recorded at one second intervals in the aircraft. Under normal flying conditions this corresponds to a data point approximately every 200 feet. Following completion of the 1985 field work, data on the HP disks were transferred to an IBM microcomputer for further processing. The 1986 field data was stored directly on IBM Compatible disks. Table G-6 lists the equations employed to convert raw voltages to scientific units for the various parameters.

DATA VALIDATION

The aircraft data system operated throughout the study period without major failure. Voltage readings from the HP 3497 were read by the HP-85 and converted to scientific units, using the appropriate equations shown in Table G-6. The IBM PC performed the same functions during the 1986 study. A continuous record of ozone concentrations was also obtained on a strip chart recorder in the aircraft. A second channel on the strip chart recorder was utilized to acquire a real time record of NO_x.

Data validity screening was accomplished entirely by manual methods. Instrument operator notes were used to determine times at which instrument range changes, zero checks and span checks were made. Whenever possible disk data were compared with strip chart data. Since ozone data were continuously recorded by both mechanisms, data validity could be double checked for that parameter.

TABLE G-6. DATA PROCESSING EQUATIONS

Parameter	1985 Equations	1986 Equations
Altitude (10's of feet)	ALT = V (3500) + 100 (Baro. Pres. - 29.22)	ALT = $(\frac{\text{Altimeter setting}}{29.22} \times \frac{2950}{2047})$ D + 50
Temperature(°C)	TMP = 320.5 x Tan[2(V - 0.50)]	TMP = $(\frac{50}{2047})$ D
Ozone (ppb)	O_3 = V(200)	O_3 = (5.095 x 10^{-2}) D - 1.1
NO/NO_x (ppb)	NO/NO_x = V (Inst. Range)	NO = (2.324 x 10^{-2}) D - 1.6 NO_x = (2.404 x 10^{-2}) D - 2.3
Relative Humidity	RH = 3.321$(100\ V)^{0.76}$- 6.56 + 0.4 (TMP)	RH = direct readout

V = Voltage output from HP system

D = digital output from IBM system

Any rapid increases or decreases for a particular parameter were examined carefully to see if there was a logical reason for the change. For example, a sharp decrease in ozone was compared with the same NO_x time profile to see if there was a corresponding increase in NO or NO_2.

The only time data were removed from the record was when an instrument malfunctioned or during the short transition period between a range change. In the latter case, about 10 scans (10 sec) were eliminated when an instrument range change occurred. Data recovery was greater than 90% for all parameters.

The aircraft flight path was reconstructed based on flight notes recorded by the pilot. Distances and angles from a local VOR were used to establish the aircraft's position at any given time. Uncertainty in location is estimated to be at most one mile.

SECTION 3

NMOC SAMPLING AND ANALYSIS

Several samples for individual hydrocarbon and aldehyde analysis were collected during each flight. Stainless steel canisters were used to collect hydrocarbon samples. These canisters have had their inner surfaces deactivated by the "Summa" process. A metal bellows pump was used to pressurize these containers to 16 psig which provided approximately five liters of air for analytical analyses. The sample canisters were cleaned by flushing with an inert gas (nitrogen) and shipped to the field site under a small positive pressure. Immediately prior to an aircraft mission, they were evacuated to low pressure. Ambient air was collected in the canisters by pumping through a critical orifice. The resulting integrated air sample represents hydrocarbon levels over a ten minute section of the flight path. During 1985, all hydrocarbon samples were returned to our Pullman, WA laboratory for analysis. Storage time between collection and analysis averaged about four days. In 1986, analyses were performed on a same day basis since the analytical instrumentation was present at the field site.

Sep-Pak cartridges (silica) impregnated with 2,4-dinitrophenyl hydrazine (DNPH) were employed for collecting carbonyl compounds. The aldehydes and ketones form stable hydrazone derivatives that can be measured using liquid chromatographic techniques. Air was drawn through an impregnated cartridge at approximately three liters per minute for 20 minutes. The exact volume of air was measured with a Tylan mass flow meter and totalizer. Immediately after collection, the sample cartridges were sealed with Teflon plugs and placed in sealed containers for shipment to Pullman, WA for analysis. Except during shipment, the cartridges were stored in a refrigerator to minimize possible artifact formation.

For the Dallas-Ft. Worth and Tulsa sampling programs, Florisil-packed Sep-Pak cartridges impregnated with the DNPH reagent were used. However high background aldehyde values were periodically observed on the Florisil-packed cartridges. Consequently, silica packed Sep-Pak cartridges were used for the remainder of the sampling program.

Samples for PAN analysis were collected in Tedlar bags. The PAN sample collections were integrated over approximately the same time and distance as the hydrocarbons and carbonyls samples. The bags were filled by ram-air flow off the aircraft's sample manifold. A needle valve was placed in the transfer line to regulate the fill rate. Care was exercised to keep the bags out of direct sunlight and to avoid exposure to elevated temperatures. PAN analyses were performed as soon as possible after the aircraft landed (within 2 hrs).

Individual Hydrocarbon Analysis - Gas chromatographic analyses were performed with Perkin Elmer and Hewlett Packard chromatographs equipped with subambient temperature programming capabilities. The column used to separate light hydrocarbons (C_2-C_5) was a packed capillary (20' x 1/16") containing Durapak n-Octane/Porasil C. When operated with a carrier gas (He) flow of 5 cm^3/min and temperature programmed from -60° to 80°C at 24°/min, this column provided excellent resolution of the light hydrocarbon fraction. A SE-30 fused silica capillary column (J & W Scientific) was used to separate hydrocarbons in the C_5 to C_{10} molecular weight range. Helium was used as the carrier gas with column flow maintained at 1 cm^3/min. Optimum results were obtained by temperature programming from -50° to 80°C at 4°/min.

Both gas chromatographs were calibrated with a 0.204 ppm 2,2-dimethylbutane (neohexane) standard (S/N# A-1934) purchased from Scott Environmental Technology, Inc. The 0.204 ppm concentration was verified in the WSU laboratory through comparison with n-hexane standards prepared by a static dilution method. The 2,2-dimethylbutane is compatible with both columns used for hydrocarbon analyses. Measured volumes of the standard were injected into the gas chromatograph. From the recorded area responses, a graph was constructed which related area counts to weight of 2,2-dimethylbutane injected. An area count per nanogram factor was determined which was used to convert peak areas in an ambient air chromatogram to nanograms of hydrocarbbon. Since the volume of sample air is carefully measured, the concentration of each hydrocarbon can be calculated in units of $\mu g/m^3$. Concentrations in ppbC units were obtained by multiplying $\mu g/m^3$ by 1.5.

The 1.5 factor was chosen for the following reasons: (1) EPA used 1.5 for interconverting between $\mu g/m^3$ and ppmC units when the recommended Air Quality Standard for Hydrocarbons was published.* The 1.5 factor is derived from methane at 1 atm pressure and 25°C. (2) WSU has used this factor in all previous reports in which hydrocarbon data were included; therefore, direct comparisons can be made between data sets. Methane has a hydrogen to carbon content of 4 to 1 which is considerably larger than the approximate 2 to 1 expected for an actual mixture of atmospheric hydrocarbons.** A more correct factor to use is 1.7 determined from neohexane at 1 atm and 25°C. Known concentrations of neohexane were used for GC calibration. In using the 1.7 factor one can directly convert the area counts to concentration factor from units of area counts per $\mu g/m^3$ to area counts per ppbC. Consequently the ppbC concentrations reported herein should be multiplied by a 1.7/1.5 factor.

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* Federal Register 36:8186 (1971)

** H. Westberg, W. Lonneman and M. Holdren, Identification and Analysis of Organic Pollutants in Air, L. H. Keith, ed., Ann Arbor Science (1984).

The 0.204 ppm neohexane standard was run on each chromatograph several times during the study period. If the area counts for a 100 cc injection of this external standard varied more than 10% from the previous run, ambient sample analysis was discontinued until the reason for the variance was determined. The coefficient of variance for neohexane runs on each GC system during the study period was less than 9% (see Table G-7).

TABLE G-7. GC RESPONSE OBTAINED FOR 100 cc INJECTION OF 0.204 ppm NEOHEXANE STANDARD

Dates	N	Mean Area Counts	Standard Deviation	Coef Variation
		C_2-C_5 Hydrocarbon GC		
7/11-9/2/85	17	15,075	1,203	7.9%
7/10-8/15/86	58	14,638	1,128	7.7%
		C_5-C_{10} Hydrocarbon GC		
7/11-9/5/85	16	1,096	93	8.5%
7/10-8/15/86	31	849	74	8.7%

It is obvious from the foregoing discussion of calibration techniques that we did not attempt to determine response factors for each of the hydrocarbon species present in ambient atmospheres. Consequently, the assumption must be made that relative sensitivities are the same for all hydrocarbons. This is not absolutely true but the work of Dietz* has shown that relative responses for the majority of species that contain only carbon and hydrogen vary by only about 5%. Thus, the assumption is made that the flame ionization detector response for a fixed amount of hydrocarbon is the same for all species. Needless to say, it would be impractical to try to determine individual response factors for the one hundred or so peaks that are normally recorded in an urban air sample.

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* W. A. Dietz, J. Gas Chromatog., 5, 68 (1967).

Hydrocarbon audits were not conducted during the study period. However, a number of samples were exchanged between WSU, the EPA Gas Kinetics and Photochemistry Lab* and in some cases the Tulsa County Health District for the purpose of comparing hydrocarbon analytical results. Table G-8 lists the analytical results obtained from four 1985 samples analyzed by the EPA and WSU laboratories. Table G-9 shows intercomparability of WSU, EPA and Tulsa County Health District Analyses. Intercomparison results for 1986 are listed in Tables G-10 and G-11. Generally speaking, individual hydrocarbon concentrations reported by WSU and EPA were in excellent agreement. However, EPA's NMHC total obtained by summing the individual species was almost always larger than WSU's. In most cases, this was due to a larger unknown (e.g. C_9-olefins, C_{12}-aromatics) fraction recorded by EPA.

Carbonyl Analysis - A Varian Vista Model 55 automated liquid chromatograph equipped with a Rheodyne automatic valve and a C_{18} reverse phase column (Rainin) was employed for aldehyde analysis. The mobile phase consisted of a 68% acetonitrile - 32% water mixture. Aldehydes were identified on the basis of retention time comparisons with standards. Separation of the hydrazone derivatives under the LC conditions described above was excellent and retention times were reproducible. Calibration curves prepared from UV detector response vs. known hydrazone concentration were established for each carbonyl compound of interest.

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* The GC Procedures for the EPA Gas Kinetics and Photochemistry Branch are included in Research Protocol Methods ASRL-ACPD-RPM 001 and ASRL-ACPD-RPM 002.

TABLE G-8. INTERCOMPARISON OF HYDROCARBON ANALYSIS BY WSU AND EPA

Sample No.	79		81		83	
	WSU (ppbC)	EPA (ppbC)	WSU (ppbC)	EPA (ppbC)	WSU (ppbC)	EPA (ppbC)
Ethane	1.6	1.0	1.2	0.9	1.7	0.8
Acetylene	0.1	1.1	-	0.2	*	0.2
Propane	0.7	0.8	0.4	0.4	0.7	0.8
Propene	0.2	0.2	0.1	0.2	0.7	1.0
i-Butane	0.4	0.6	0.2	0.4	0.2	0.2
n-Butane	0.2	0.4	0.1	0.2	0.3	0.4
i-Pentane	-	0.2	0.3	0.1	0.4	0.4
n-Pentane	-	0.6	0.2	0.1	0.3	0.2
Cyclopentane	-	-	-	-	-	-
Isoprene	-	-	-	-	-	0.1
2-Methylpentane	0.1	-	0.1	-	0.1	1.0
3-Methylpentane	-	-	-	-	-	3.2
n-Hexane	0.2	-	0.1	-	-	-
Methylcyclopentane	-	-	-	-	-	-
Benzene	0.2	0.2	0.2	0.1	0.2	0.7
Cyclohexane	-	-	-	-	-	-
3-Methylhexane	-	-	-	-	-	-
Toluene	0.3	0.2	0.6	0.4	0.5	0.5
Ethylbenzene	0.1	-	0.1	-	0.2	0.3
p & *m*-Xylene	0.1	-	0.2	-	0.2	0.4
o-Xylene	0.1	-	0.1	-	0.1	-
Total Identified HC	4.1	5.1	3.9	3.0	5.6	10.2
TOTAL NMHC	4.2	-	5.1	-	5.6	-

(cont'd.)

TABLE G-8. (Continued)

Sample No.	91					
	WSU (ppbC)	EPA (ppbC)	WSU (ppbC)	EPA (ppbC)	WSU (ppbC)	EPA (ppbC)
Ethane	1.5	1.6				
Acetylene	-	0.3				
Propane	0.6	0.6				
Propene	0.1	0.1				
i-Butane	0.5	0.7				
n-Butane	0.3	0.3				
i-Pentane	0.4	0.3				
n-Pentane	0.3	0.2				
Cyclopentane	-	-				
Isoprene	0.1	-				
2-Methylpentane	0.2	-				
3-Methylpentane	0.1	-				
n-Hexane	0.3	-				
Methylcyclopentane	0.2	-				
Benzene	0.1	-				
Cyclohexane	-	-				
3-Methylhexane	-	-				
Toluene	0.3	0.3				
Ethylbenzene	0.3	0.1				
p & *m*-Xylene	0.3	0.2				
o-Xylene	0.1	-				
Total Identified HC	5.7	4.7				
TOTAL NMHC	6.2	-				

TABLE G-9. INTERCOMPARISON OF 1985 HYDROCARBON ANALYSIS BY WSU, EPA AND TULSA COUNTY HEALTH DEPARTMENT (TCHD)

Sample No.	33			34		
	WSU (ppbC)	EPA (ppbC)	TCHD (ppbC)	WSU (ppbC)	EPA (ppbC)	TCHD (ppbC)
Ethane	6.4	6.1	*	3.9	9.1	*
Acetylene	0.5	0.3	*	-	-	*
Propane	5.2	5.9	9.9	2.9	4.6	3.7
Propene	-	-	-	-	0.1	-
i-Butane	1.0	1.3	0.9	0.6	0.8	-
n-Butane	2.3	2.8	2.3	1.5	2.1	1.5
i-Pentane	0.8	0.9	0.9	0.7	1.3	0.8
n-Pentane	0.7	0.4	0.8	-	0.4	1.8
Cyclopentane	0.2	-	-	2.4	3.1	2.2
Isoprene	-	-	-	4.0	-	4.2
2-Methylpentane	0.2	0.2	-	-	0.2	-
3-Methylpentane	0.1	0.6	1.2	-	1.9	1.8
n-Hexane	0.2	0.3	-	-	0.3	-
Methylcyclopentane	0.1	0.1	-	-	0.1	-
Benzene	0.4	0.7	-	-	0.5	-
Cyclohexane	-	-	-	-	-	-
3-Methylhexane	0.9	-	-	1.0	-	-
Toluene	0.3	0.3	1.2	-	0.9	-
Ethylbenzene	-	-	-	-	0.2	-
p & *m*-Xylene	-	-	-	-	-	-
o-Xylene	-	-	-	-	-	-
Total Identified HC	19.3	19.9	17.2	17.0	25.6	16.0
TOTAL NMHC	22.9	-	25.9	21.4	-	18.8

* TCHD analysis was carried out in a single run, for each sample. Ethane and Acetylene did not separate from the ethylene peak. Therefore, these are not represented in the data provided here.

(cont'd.)

TABLE G-9. (Continued)

Sample No.	35			52		
	WSU (ppbC)	EPA (ppbC)	TCHD (ppbC)	WSU (ppbC)	EPA (ppbC)	TCHD (ppbC)
Ethane	5.0	10.4	*	15.3	19.7	*
Acetylene	0.7	-	*	0.7	-	*
Propane	3.7	5.9	5.2	11.8	13.5	14.7
Propene	0.3	0.1	-	0.3	0.1	-
i-Butane	1.1	1.6	0.9	2.4	2.5	2.7
n-Butane	1.6	2.5	1.5	5.7	6.4	6.7
i-Pentane	0.9	1.3	0.9	1.9	2.5	2.6
n-Pentane	0.7	1.8	-	1.9	1.1	4.9
Cyclopentane	1.0	-	0.9	-	0.1	-
Isoprene	0.2	0.3	-	0.1	-	-
2-Methylpentane	0.3	0.4	-	0.4	0.7	-
3-Methylpentane	0.1	1.5	1.4	0.3	0.7	-
n-Hexane	0.3	0.4	-	0.7	0.8	1.0
Methylcyclopentane	-	0.1	-	0.3	0.3	-
Benzene	0.8	1.1	-	0.5	0.6	-
Cyclohexane	-	-	-	-	-	-
3-Methylhexane	1.4	-	-	0.3	0.4	-
Toluene	0.6	1.0	-	0.5	0.6	1.5
Ethylbenzene	0.5	0.2	-	0.1	0.1	-
p & *m*-Xylene	0.3	-	-	0.2	-	2.0
o-Xylene	0.4	-	-	0.2	0.6	-
Total Identified HC	19.9	28.6	10.8	43.6	50.0	36.1
TOTAL NMHC	23.0	-	14.2	43.6	-	45.2

(cont'd.)

TABLE G-9. (Continued)

Sample No.	53			54		
	WSU (ppbC)	EPA (ppbC)	TCHD (ppbC)	WSU (ppbC)	EPA (ppbC)	TCHD (ppbC)
Ethane	8.5	8.5	*	15.3	17.0	*
Acetylene	0.7	0.6	*	0.6	0.5	*
Propane	6.5	8.0	4.8	12.3	14.2	14.3
Propene	-	0.3	-	0.7	-	-
i-Butane	1.5	1.4	1.5	2.5	2.7	2.9
n-Butane	2.9	3.5	3.4	6.2	7.3	7.3
i-Pentane	1.1	1.4	1.4	1.9	1.3	3.1
n-Pentane	0.9	1.2	1.3	2.1	1.0	2.7
Cyclopentane	0.2	-	-	0.2	0.1	-
Isoprene	0.1	-	-	0.1	0.9	-
2-Methylpentane	0.3	-	-	0.7	0.8	4.4
3-Methylpentane	0.2	-	2.5	0.4	0.5	-
n-Hexane	-	-	-	0.8	0.9	1.0
Methylcyclopentane	0.2	0.4	-	0.3	0.3	-
Benzene	0.5	0.5	-	1.0	1.5	-
Cyclohexane	-	-	-	-	0.2	-
3-Methylhexane	0.3	-	-	0.3	0.2	-
Toluene	0.4	1.3	1.4	0.8	1.2	2.3
Ethylbenzene	-	0.2	-	0.3	0.3	0.8
p & *m*-Xylene	0.2	-	2.6	0.4	0.7	3.4
o-Xylene	0.1	-	1.0	0.5	0.4	1.8
Total Identified HC	24.6	27.3	20.0	47.4	52.0	44.0
TOTAL NMHC	24.6	-	35.3	55.5.1	-	68.1

(cont'd.)

TABLE G-9. (Continued)

Sample No.	55		
	WSU (ppbC)	EPA (ppbC)	TCHD (ppbC)
Ethane	21.9	23.0	*
Acetylene	0.6	0.5	*
Propane	22.0	26.7	21.8
Propene	-	-	-
i-Butane	3.9	4.9	4.1
n-Butane	11.7	14.1	11.9
i-Pentane	3.6	4.7	3.9
n-Pentane	4.1	2.8	5.2
Cyclopentane	-	0.3	-
Isoprene	-	-	-
2-Methylpentane	1.1	1.4	1.4
3-Methylpentane	0.6	2.2	2.5
n-Hexane	1.3	1.8	1.9
Methylcyclopentane	0.6	0.7	-
Benzene	0.5	0.8	-
Cyclohexane	-	-	-
3-Methylhexane	-	0.8	1.6
Toluene	0.4	0.8	2.2
Ethylbenzene	-	0.2	0.8
p & *m*-Xylene	-	0.2	4.0
o-Xylene	-	-	1.4
Total Identified HC	72.3	85.2	62.7
TOTAL NMHC	72.7	-	85.8

TABLE G-10. WSU - EPA HYDROCARBON INTERCOMPARISON (PHILADELPHIA - 1986)

Sample No.	WSU #1		WSU #2		WSU #4	
	WSU (ppbC)	EPA (ppbC)	WSU (ppbC)	EPA (ppbC)	WSU (ppbC)	EPA (ppbC)
Ethane	21.5	22.8	4.3	4.5	8.4	11.0
Acetylene	6.5	10.5	0.1	0.4	7.5	15.0
Propane	16.1	18.4	2.1	2.6	12.6	15.7
Propene	4.6	3.9	-	-	3.6	6.9
i-Butane	20.9	21.0	0.5	0.9	16.2	19.2
n-Butane	46.3	46.1	2.3	1.8	39.0	43.2
i-Pentane	56.4	54.4	1.6	0.8	40.1	44.2
n-Pentane	29.5	29.4	0.8	0.2	17.0	25.7
Cyclopentane	2.4	2.4	-	-	1.2	*
Isoprene	2.0	3.1	-	-	0.8	*
2-Methylpentane	22.7	19.9	0.4	0.3	11.3	*
3-Methylpentane	13.7	15.1	-	-	6.9	*
n-Hexane	17.6	16.7	0.3	0.3	6.5	1.0
Methylcyclopentane	8.0	8.0	-	0.1	4.6	9.1
Benzene	17.3	16.2	1.2	0.6	12.9	13.3
Cyclohexane	2.3	2.2	-	-	0.6	1.6
3-Methylhexane	6.9	6.6	0.1	0.1	4.2	1.2
Toluene	39.6	37.1	2.0	0.6	34.8	37.1
Ethylbenzene	7.4	5.7	-	-	6.6	7.4
p & *m*-Xylene	21.9	19.7	0.7	0.1	27.0	27.3
o-Xylene	9.6	8.6	1.0	0.2	11.7	*
Total	372.9	367.8	17.4	13.5	273.5	*

NOTE: - means less than 0.1 ppbC

* interference

(cont'd.)

TABLE G-10. (continued)

Sample No.	WSU #5		WSU #6		WSU #7	
	WSU (ppbC)	EPA (ppbC)	WSU (ppbC)	EPA (ppbC)	WSU (ppbC)	EPA (ppbC)
Ethane	3.7	3.4	3.9	4.1	18.0	19.3
Acetylene	0.6	0.7	0.3	0.4	8.5	*
Propane	1.8	1.4	2.3	2.4	33.6	37.3
Propene	-	0.2	-	-	9.4	9.6
i-Butane	0.7	0.9	0.5	0.6	21.9	21.9
n-Butane	2.0	1.9	1.5	1.3	57.0	54.4
i-Pentane	2.0	1.9	0.9	0.7	47.8	*
n-Pentane	0.9	0.6	0.5	0.3	22.7	21.5
Cyclopentane	-	-	-	-	1.8	1.8
Isoprene	-	0.1	-	-	1.1	1.0
2-Methylpentane	0.3	0.3	0.1	-	16.1	15.5
3-Methylpentane	0.2	3.7	-	-	10.0	9.9
n-Hexane	0.1	0.3	0.1	-	9.9	9.1
Methylcyclopentane	-	-	-	-	6.2	5.8
Benzene	0.9	0.6	0.3	-	15.5	15.0
Cyclohexane	-	-	-	-	1.8	1.7
3-Methylhexane	0.8	0.1	-	-	5.2	6.3
Toluene	2.2	2.1	0.8	0.2	40.1	39.9
Ethylbenzene	0.5	0.3	-	-	9.5	9.3
p & *m*-Xylene	2.2	1.6	0.5	-	29.8	29.6
o-Xylene	2.2	2.8	0.5	-	11.6	13.0
Total	21.1	22.9	12.2	10.0	377.5	*

(cont'd.)

TABLE G-10. (continued)

Sample No.	WSU #9		WSU #10	
	WSU (ppbC)	EPA (ppbC)	WSU (ppbC)	EPA (ppbC)
Ethane	11.7	14.1	7.4	3.2
Acetylene	5.7	9.2	0.3	0.5
Propane	11.1	13.2	1.9	1.7
Propene	4.1	5.0	-	-
i-Butane	9.3	10.7	0.5	0.4
n-Butane	24.1	26.7	1.0	0.9
i-Pentane	25.6	29.4	0.7	0.5
n-Pentane	10.7	11.4	0.3	0.1
Cyclopentane	0.9	1.0	-	-
Isoprene	0.6	0.6	-	-
2-Methylpentane	8.5	8.6	0.1	-
3-Methylpentane	*	*	-	-
n-Hexane	4.4	4.8	0.1	-
Methylcyclopentane	3.3	3.4	-	-
Benzene	3.3	9.9	0.3	0.1
Cyclohexane	0.9	0.6	-	-
3-Methylhexane	4.1	4.3	-	-
Toluene	28.8	30.5	0.5	-
Ethylbenzene	4.8	4.1	-	-
p & *m*-Xylene	13.7	15.1	-	0.4
o-Xylene	6.0	7.1	-	-
Total	181.6	209.7	13.1	7.8

(cont'd.)

TABLE G-10. (continued)

Sample No.	WSU #11		WSU #12		WSU #14	
	WSU (ppbC)	EPA (ppbC)	WSU (ppbC)	EPA (ppbC)	WSU (ppbC)	EPA (ppbC)
Ethane	13.6	15.3	9.3	11.1	11.3	12.5
Acetylene	10.2	16.2	7.0	11.4	5.2	8.8
Propane	15.4	16.6	11.1	12.4	15.0	15.7
Propene	3.3	7.2	4.8	3.8	5.0	4.3
i-Butane	18.9	20.2	7.7	8.6	11.9	12.0
n-Butane	41.3	42.9	20.2	21.6	33.3	33.4
i-Pentane	48.1	50.0	20.3	23.4	31.6	29.9
n-Pentane	19.6	20.5	8.6	8.3	12.6	14.5
Cyclopentane	1.4	1.9	1.4	0.7	1.0	1.3
Isoprene	2.0	1.7	0.7	0.5	0.8	1.1
2-Methylpentane	16.5	16.0	6.2	6.0	10.3	8.4
3-Methylpentane	9.0	*	3.1	9.8	7.5	7.1
n-Hexane	8.0	8.4	3.9	3.7	5.9	5.5
Methylcyclopentane	5.8	5.8	2.4	2.4	3.7	3.3
Benzene	16.1	15.3	7.4	6.7	9.4	8.8
Cyclohexane	1.1	1.0	1.1	0.4	0.7	0.7
3-Methylhexane	5.9	6.1	2.5	2.2	3.1	4.6
Toluene	53.5	54.7	20.4	18.9	25.0	25.6
Ethylbenzene	6.8	7.1	2.7	2.8	3.6	3.8
p & *m*-Xylene	22.2	23.8	9.1	10.0	13.7	14.1
o-Xylene	8.8	9.5	4.8	4.4	7.3	6.6
Total	327.5	340.2	154.7	169.1	217.9	222.0

TABLE G-11. TOTAL NMOC DATA FOR INTERCOMPARISON SAMPLES COLLECTED IN PHILADELPHIA DURING 1986 (Concentration = ppbC)

SAMPLE	DATE	SITE	WSU		GKPD	
			FID	FID*	FID	FID*
WSU-1	7/14	LAB	597	569	690	
WSU-2	7/14	AC-2	97.8	36.9	84.3	
WSU-4	7/22	DS	402	370	911	
WSU-5	7/23	AC-3	25.2	23.0	136	
WSU-6	7/30	AC-1	18.1	14.7	38.4	
WSU-7	7/29	SE	534	522	816	
WSU-9	8/3	CHS	2548	543	3080	
WSU-10	8/12	AC-2	14.7	14.7	50.1	
WSU-11	8/14	B	1578	277	1989	
WSU-12	8/15	SE	235	235	349	
WSU-13	8/15	LAB	ND	ND	1245	
WSU-14	8/15	DS	336	336	452	
WSU-15	8/15	CHS	ND	ND	2310	

NOTES:

FID*:	Artifact (contamination) peaks removed.
LAB:	Air Quality lab on Lycoming Street.
AC:	Aircraft.
DS:	Delaware and Spring Garden.
SE:	Southeast water treatment.
CHS:	County Health (Broad and Lombard).
B:	Belmont.

Prior to the beginning of the field study, several quality assurance tests were performed. Factors such as stability of exposed cartridges during shipment, integrity during storage and intercomparability of aldehyde concentrations between two independent laboratories were examined. The U.S. Environmental Protection Agency (ASRL-RTP) participated with us in this intercomparison study.

On May 31, 1985 personnel at the EPA laboratory collected three sets of four cartridge samples in outside, ambient air. Four Tylan flow controllers were used to collect 60 liters of air at flowrates of 1 L/min. Samples I-2 and I-4 from Set I, samples II-1 and II-3 from Set II, samples III-2 and III-4 from Set III, and 4 blank cartridges were sent to WSU. Upon arrival, WSU returned all samples of Set III and 2 blanks to EPA. WSU analyzed the four air samples from Sets I and II and 2 blanks. EPA analyzed all other samples collected in the three sets. Some of the samples analyzed by EPA were stored under refrigeration before analysis while others were stored at room temperature. The purpose of this analysis sequence was to evaluate storage effects during commercial shipment and to determine injection precision. Consequently, repeat injections were performed on several samples. Details of these analyses are shown in Table G-12.

A second intercomparison study was begun on June 14, 1985. EPA collected four sets of 4 cartridge samples using outside ambient air. SEP-PAK-Silica cartridges were used for these samples. Four Tylan flow controllers were used to collect 60 liters of air at flowrates of 1 L/min. Samples I-1 and I-3 from Set I, samples II-2 and II-4 from Set II, all samples from Set III and 4 blank cartridges were sent to WSU. Upon arrival, WSU returned all samples of Set III and 2 blanks to EPA. WSU analyzed the four air samples from Sets I and II and 2 blanks. The purpose of this analysis sequence was to evaluate cartridge storage effects during commercial shipment. EPA kept all samples from Set IV and performed a long-term storage study with the cartridge samples kept under refrigeration. Details of these sample analyses are shown in Table G-13. Samples II-1, II-3, and IV-2 were inadvertently misplaced and were not analyzed by EPA.

TABLE G-12 RESULTS OF ALDEHYDE INTERCOMPARISON STUDY FOR SAMPLES COLLECTED BY EPA ON MAY 31, 1985. CONCENTRATIONS ARE IN ppb COMPOUND.

	EPA Analysis		WSU Analysis	
Sample No.	Formaldehyde	Acetaldehyde	Formaldehyde	Acetaldehyde
I - 1	2.3	1.3		
I - 1(R)	2.3	1.4		
I - 2			2.6	ND
I - 3*	2.4	1.7		
I - 4			2.4	1.2
II - 1			3.9	<0.5
II - 2	2.7	1.7		
II - 2(R)	2.5	1.8		
II - 3			4.4	ND
II - 4	2.9	1.9		
II - 4(R)	2.9	1.9		
III - 1	3.9	2.4		
III - 2(M)	3.8	2.3		
III - 3	4.4	2.1		
III - 3(R)	4.3	2.0		
III - 4(M)	3.6	2.0		

(R) = Repeat analysis
* = Cartridge sample stored in refrigerator for 12 days before analysis
(M) = Mailed to Pullman, WA and returned to RTP before analysis.

The results of these initial tests indicated that there were no major problems associated with shipment or storage of the aldehyde-DNPH samples. Also, aldehyde concentrations reported by the WSU and EPA laboratories were comparable. The QA/QC comparison studies continued after commencement of the field study program. The design of the aircraft sampling program did not permit the collection of paired samples which is the desired approach for the comparison study. Instead EPA was sent all cartridge samples collected for one of the sampling days. It was anticipated that background organic carbonyl concentrations would not change significantly from day to day over the sampling period. Consequently, useful comparisons between WSU and EPA analyses could be made. Along with the shipment of the exposed cartridge samples (typically 3 samples), WSU included one or two blank cartridges that had traveled with the sample cartridge but had never been intentionally exposed to ambient air.

TABLE G-13. RESULTS OF ALDEHYDE INTERCOMPARISON STUDY FOR SAMPLES COLLECTED BY EPA ON JUNE 14, 1985. CONCENTRATIONS ARE IN ppb COMPOUND.

Sample No.	EPA Analysis			WSU Analysis	
	Formaldehyde	Acetaldehyde		Formaldehyde	Acetaldehyde
I - 1				3.8	2.8
I - 2	3.0	1.8			
I - 3				3.4	2.2
I - 4	3.7	1.9			
II - 1	ND	ND			
II - 2				5.3	5.1
II - 3	ND	ND			
II - 4				4.3	3.6
III - 1(M)	3.9	2.4			
III - 2(M)	4.0	2.8			
III - 3(M)	4.3	2.6			
III - 4(M)	4.3	2.0			
IV - 1	4.3	2.5	(Analyzed 3 days after collection)		
IV - 3	ND	ND			
IV - 3	3.8	2.1	(Analyzed 6 days after collection)		
IV - 4	4.3	2.6	(Analyzed 41 days after collection)		

(M) = Mailed to Pullman, WA and returned to RTP before analysis.

Table G-14 lists aldehyde levels measured aloft during the three day period August 5-7, 1985. WSU determined the concentrations on August 5 and 7 while the August 6 concentrations were measured by EPA. The analytical results from both groups indicate that the formaldehyde and acetaldehyde concentrations were generally less than one part per billion.

TABLE G-14. FORMALDEHYDE AND ACETALDEHYDE CONCENTRATIONS (ppb) MEASURED ALOFT

Date	Sample No.	Formaldehyde	Acetaldehyde	Analysis By
8/5/86	S-10	<0.7	0.6	WSU
"	S-11	<0.8	1.0	WSU
"	S-12	<0.8	1.0	WSU
8/6/86	S-14	0.5	0.3	EPA
"	S-15	0.3	0.2	EPA
"	S-16	1.5	0.3	EPA
8/7/86	S-17	<0.8	0.3	WSU
"	S-18	<0.8	0.2	WSU
"	S-19	<0.8	<0.2	WSU

PAN analysis - An Analog Technology Corporation Model 140B electron capture gc system (EPA #40175) was used for measuring PAN. Argon/methane (95/5%) carrier gas was passed through a 3'x1/8" o.d. column packed with 10% Carbowax on Chrom Z (70-80 mesh) at 70 cc/min. A five cc sample loop was used to introduce the sample into the gc system. Low concentration PAN in air mixtures were made in Tedlar (PVF) bags for calibration purposes. Known concentrations of PAN were prepared by injecting aliquots from a synthesized PAN mixture (gas phase irradiation of acetaldehyde, chlorine and NO_2 mixtures) into known volumes of air in the Tedlar bags. The actual concentration of PAN was determined using a calibrated ECD-GC system (Northrop Corporation). Four

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8/6/86	S-14	0.5	0.3	EPA
"	S-15	0.3	0.2	EPA
"	S-16	1.5	0.3	EPA
8/7/86	S-17	<0.8	0.3	WSU
"	S-18	<0.8	0.2	WSU
"	S-19	<0.8	<0.2	WSU

PAN analysis - An Analog Technology Corporation Model 140B electron capture gc system (EPA #40175) was used for measuring PAN. Argon/methane (95/5%) carrier gas was passed through a 3'x1/8" o.d. column packed with 10% Carbowax on Chrom Z (70-80 mesh) at 70 cc/min. A five cc sample loop was used to introduce the sample into the gc system. Low concentration PAN in air mixtures were made in Tedlar (PVF) bags for calibration purposes. Known concentrations of PAN were prepared by injecting aliquots from a synthesized PAN mixture (gas phase irradiation of acetaldehyde, chlorine and NO_2 mixtures) into known volumes of air in the Tedlar bags. The actual concentration of PAN was determined using a calibrated ECD-GC system (Northrop Corporation). Four low concentration sample bags were prepared and analyzed on the calibrated ECD-GC system. Sample aliquots from these measured bags were then injected into the field GC-ECD system. The results are given below:

Bag	PAN CONC.	Areas Response on Field GC-ECD System	Response Factor
1	22 ppb	1.497×10^8	6.8×10^6 area count ppb^{-1}
2	9 ppb	0.960×10^8	10.0×10^6 area count ppb^{-1}
3	9 ppb	0.970×10^8	10.0×10^6 area count ppb^{-1}
4	14 ppb	1.01×10^8	7.2×10^6 area count ppb^{-1}

Average Response Factor $8.5 \pm 1.7 \times 10^6$ area count ppb^{-1}

The average response factor of 8.5×10^6 area count ppb^{-1} was used for the field GC-ECD system during the course of the field study effort. Daily fluctuation of the PAN calibration factor was adjusted by the analysis of a methyl nitrate in nitrogen standard that had an area count measurement of 1.02×10^8 area count on the day of the PAN calibration.

To determine storage stability of PAN in Tedlar bags, two tests were performed. PAN samples for the storage studies were prepared by the injection of aliquots of a prepared PAN mixture into the bags containing known volumes of air. Samples from the bags were periodically injected into the GC-ECD systems. The results for the Tedlar bag storage studies are given in Table G-15.

TABLE G-15. PAN STORAGE STABILITY IN 70 liter 2 mil TEDLAR (PVF) BAGS

Test I[*]		Test II[+]	
Time (min)	PAN (ppb)	Time (min)	PAN (ppb)
0	5.8	0	9.2
30	6.0	30	9.4
60	6.2	60	9.9
420	5.6		
1200	0.2		

[*] Room temperature varied between 21.5 and 23.0°C during storage period.

[+] Room temperature was 21.5°C during test.